UNIVERSITY OF LINCOLN

THE DEVELOPMENT AND VALIDATION OF TOOLS AND TECHNIQUES TO ASSESS PERCEPTIONS OF FEMALE BODY SIZE/SHAPE.

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Abstract

Body image comprises two distinct yet interrelated components: i) the perceptual component which is the mental picture one has of their body and is measured by looking at body size/shape estimation accuracy, and ii) the attitudinal component which is a person's thoughts and feelings about their body size/shape and encompasses broader psychological constructs such as self-esteem and depressive thoughts. Disturbances in either or both components can have implications for a person's livelihood, may result in extreme body change behaviours, and are prevalent features of eating disorders (e.g. Anorexia and Bulimia Nervosa) and obesity.

The studies presented in this thesis were designed to develop and build on existing techniques used in perceptual body image research. Throughout seven main studies, novel measures/techniques were developed and the reliability, validity, and utility were assessed. Throughout the studies, the interactions between perceptual and attitudinal body image and the person's own body and demographic characteristics were considered.

In Study 1, an existing body size modification intervention was explored in a replication and extension study to provide further evidence of its utility in a sample of females with heightened body concerns. In Study 2, the baseline measurements from Study 1 were compared to a sample of females with low/mild body concerns, to further develop understanding of the relationship between perceptual and attitudinal components. In both studies, interactive computer software was used to assess perceptions of current and ideal body size/shape using a 3D female model.

In Study 3, body size discrimination was investigated using a psychophysical task and novel computer-generated stimuli calibrated for Body Mass Index (BMI). Using these findings,

new perceptually-spaced body scales were created and their reliability and validity were investigated in non-eating-disordered females (Study 4).

For studies 5, 6, and 7, a 3D body scan and composition database from 221 Caucasian females aged 18 - 45 was developed, to generate novel 3D stimuli. In Study 5, a selection of the scans varying in BMI, combined with a standardised computer-generated skin texture, were used to investigate BMI category perceptions and attitudes towards weight loss, in a sample of UK adults. For studies 6 and 7, a novel interactive body scale was created, using a statistical mapping between 3D shape and body composition (fat mass and skeletal muscle mass). The plausibility, reliability and validity of this novel scale were investigated and perceptions of female body composition ideals were explored in male and female observers.

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List of Commonly Used Abbreviations

2D – Two-Dimensional

3D – Three-Dimensional

AN – Anorexia Nervosa

BD – Body Dissatisfaction

BHR – Bust-to-Hip Ratio

BIA – Bioelectrical Impedance Analysis

BID – Body Image Distortion

BDD – Body Dysmorphic Disorder

BMI – Body Mass Index

BN – Bulimia Nervosa

CG – Computer-Generated

CGI – Computer-Generated Imagery

FATM – Fat Mass

FRS – Figural Rating Scale/s

JND – Just Noticeable Difference

PCA – Principal Component Analysis

SMM – Skeletal Muscle Mass

WBR – Waist-to-Bust Ratio

WHR – Waist-to-Hip Ratio

Chapter 1: General Introduction

1.1 What is Body Image?

Body image refers to the “multifaceted psychological experience of embodiment, especially but not exclusively one’s physical appearance” (Cash, 2004, p. 1). It is a person’s mental representation and experience of their own body (thoughts, feelings, and perceptions), relating to a variety of aspects related to physical appearance, including but not limited to, size, shape, leanness, athleticism, ageing, and sexual attractiveness (McLean & Paxton, 2019). In this sense, body image may be interpreted as ‘body images’; a complex and multi-dimensional construct comprised of body-related self-perceptions and attitudes (Cash & Pruzinsky, 1990).

Cash and Deagle (1997) discuss the historical assessment of body image which has concentrated on two components: perceptual and attitudinal (cognitive-affective). The perceptual component refers to the mental picture of one’s own body (Schilder, 1935; Slade, 1988). Disturbance of percept refers to an inaccurate perception of body size/shape (body image distortion) (Hosseini & Padhy, 2019; Slade, 1994). The attitudinal component refers to thoughts, beliefs, and feelings about the body, which can be positive (e.g. body satisfaction or appreciation) or negative (e.g. body dissatisfaction). These components are often considered distinct mechanisms (e.g. Cornelissen et al., 2019), such that disturbances of these components can be mutually exclusive, as someone may be able to accurately estimate their own body (perceptual component) but demonstrate dissatisfaction with their size, shape and/or appearance (attitudinal component) (Cash & Deagle, 1997). Others consider these components to be interrelated (Slade, 1994), such that a perceptual disturbance is a reflection of attitudinal and psychological distress (Ben-Tovim et al., 1990; Probst et al., 1992; Smeets et al., 1999), or at least, influenced by attitudinal, socio-cultural, and biological factors (Slade, 1994).

1.2 Importance of Body Image

Body image can influence large parts of an individual's livelihood including, mental health, emotional wellbeing, psychopathology, self-esteem, and day-to-day social interactions (Garner, 1997). Negative body image may be seen as being on a continuum from discontent to severe distress, affecting self-esteem, social well-being, and eating behaviour (Cash, 2009). A large UK survey by the Mental Health Foundation (2019) found that 40% of females reported anxious thoughts and 45% reported depressed mood as a result of body image concerns. Body dissatisfaction in adolescents predicts risky health behaviours (e.g. high-risk drinking and drug use) and self-harm (Bornioli et al., 2019). In adults, negative body image correlated with negative affect, poorer health behaviours, and lowered quality of life (Becker et al., 2019). The associations between dissatisfaction and poorer mental/physical health-related quality of life occur independently of demographic variables such as Body Mass Index (BMI) and eating disorder symptoms (Griffiths et al., 2016; Mond et al., 2013). Sharpe et al. (2018) investigated the relative importance of three factors relating to body image disturbance: dissatisfaction (negative evaluation of one's own body), overvaluation (the over-importance of body weight and shape in one's perceived self-worth) and preoccupation (frequent intrusive thoughts about one's own body). These factors were associated with clinically significant outcomes, such as disordered eating behaviours, and depression and anxiety symptoms (see also Linardon et al., 2018).

1.3 Clinical Manifestation of Body Image

Body image disturbance is associated with disordered eating patterns and weight control behaviours such as meal skipping, binge-eating, and dieting (Neumark-Sztainer et al., 2006; Stice & Shaw, 2002) and is considered a core and prevalent clinical feature of eating disorders e.g. Anorexia Nervosa (AN), Bulimia Nervosa (BN), and Body Dysmorphic Disorder (BDD) (Farrell et al., 2006; Forrest et al., 2018; Garner, 2002; Hrabosky et al., 2009; Phillipou et al., 2018, 2019). Eating disorders are serious mental illnesses with high mortality rates, physical and psychological impacts on the individual and their carers, and substantial social/economic costs (BEAT, 2015). The prevalence of eating disorders is high, with women and Caucasian adults at higher risk (Udo & Grilo, 2018). Research indicates that approximately 11% of Western females will experience an eating disorder in their lifetime (Favaro et al., 2003). Using a Bayesian model it was predicted that approximately 1 in 5 female adults in the US would experience an eating disorder by the age of 40 years old, with onset being most likely before the age of 25 (Ward et al., 2019). A longitudinal study of adolescent females suggests that the peak age of onset for most eating disorders is between 16 and 20 years old and that approximately 1 in 8 of these young women experience an eating disorder (Stice et al., 2013). Relapse is common (approximately one-third of women), especially in the first year post-treatment and may be predicted by body image concerns and decreased psychosocial functioning (Keel et al., 2005; Khalsa et al., 2017; Richard et al., 2005).

Body image disturbance is included in diagnostic criteria for both AN and BN in the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association [APA], 2013). For example, the AN criteria states, “Either an intense fear of gaining weight or of becoming fat, or persistent behaviour that interferes with weight gain (even though significantly low weight)” and “Disturbance in the way one's body weight or shape is experienced, undue influence of body shape and weight on self-evaluation, or persistent lack of recognition of the seriousness of the current low body weight”. The BN criteria states, “Self-evaluation is unduly influenced by body shape and weight” (APA, 2013). Whilst BDD is not specific to body size/shape, some authors do describe BDD as “an extreme form of body image disturbance” (Shroff et al., 2009, p. 128) and several commonalities between AN and BDD symptomology and comorbidities have been identified, including concerns and preoccupation with body size/shape, distorted body image, and low self-esteem (Enander et al., 2018; Hartmann et al., 2013; Phillipou et al., 2019). An abundance of research substantiates the key role of disturbed perceptual and/or attitudinal body image in women with eating disorders (Benninghoven et al., 2007; Hagman et al., 2015; Mölbert et al., 2017; Waldman et al., 2013). Some authors even argue that AN, BN, BDD and Muscle Dysmorphia should be re-classified as body image disorders (Phillipou et al., 2018). Benefits of a re-classification include de-stigmatisation, a reduction in public misconceptions, emphasis on prolonged therapeutic support throughout re-feeding, and a directed change in psychological research towards the underlying mechanisms that are driving body image disturbances (Phillipou et al., 2018).

1.3.1 *A Continuum of Psychopathology*

Research supports a continuum of body image disturbances and eating disorder psychopathology varying from asymptomatic to clinically severe (Garfinkel et al., 1995; Scarano & Kalodner-Martin, 1994; Tylka & Subich, 1999). Some evidence suggests that eating disorder symptomology may be at a ‘subclinical’ level for those with increased body image concerns, negative affect, and ideal-body internalisation compared to controls but lower than eating disorder patients (see e.g. Stice et al., 1996). Mintz and Betz (1988) found that 64% of their sample of college women were categorised as somewhere between and ‘normal’ and warranting a BN diagnosis based on DSM-3 criteria, implying that many women perpetually struggle with eating/body image disorder symptomology and unhealthy weight control behaviours.

Subclinical thresholds can be determined using questionnaire norms. For example, based on Body Shape Questionnaire scores (assessing body size, shape, and weight concerns), one can categorise according to level of concern (e.g. ‘marked concern with shape’ or ‘no concern with shape') (Taylor, 1987). This has been used in research to recruit women with heightened concerns for intervention implementation and evaluation (see e.g. Gledhill et al., 2017; Irvine et al., 2020). Furthermore, normative data for the Eating Disorder Examination-Questionnaire (EDE-Q) (a commonly used measure of disordered eating psychopathology; Fairburn & Beglin, 1994) have been established for a variety of different samples. Mond et al. (2006) developed age-group specific normative data based on a large sample of women (n = 10,000) aged 18 - 42 years old. Those scoring within one standard deviation of age-matched means would be considered as experiencing normal levels of eating disorder psychopathology, whereas those scoring above one standard deviation would be considered as experiencing heightened psychopathology. Bardone-Cone et al. (2010) define full eating disorder recovery as indistinguishable from healthy controls behaviourally (cessation of eating disorder behaviours), physically (a BMI above 18.50), and psychologically (scores within one standard deviation of age-matched controls on all subscales of the EDE-Q). Partial recovery is defined as meeting the behavioural and physical requirements, but not meeting the psychological requirements (i.e. scoring outside of EDE-Q norms). The authors suggest that the 'final hurdle to recovery' may be body image disturbance since the partially recovered women scored similarly to those with an active eating disorder on body image related measures (Bardone-Cone et al., 2010).

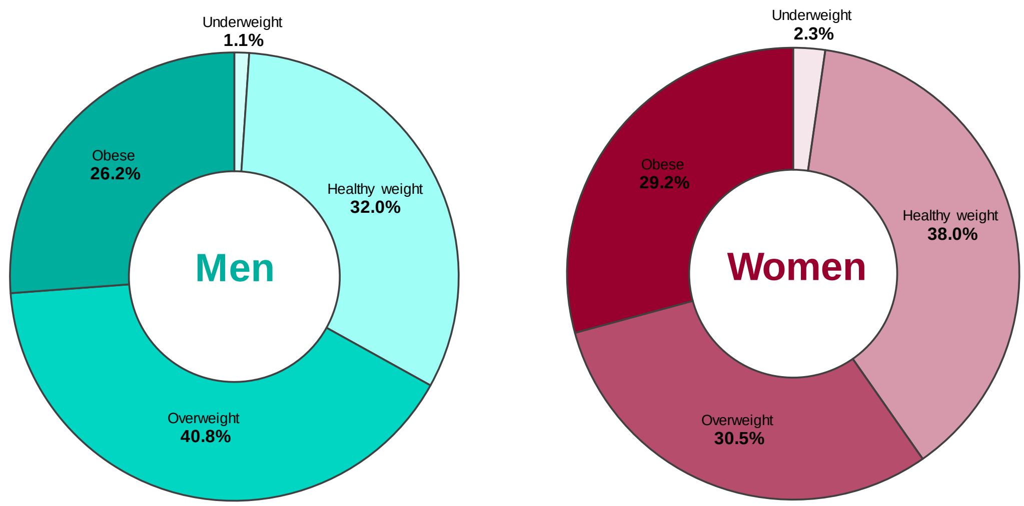
1.3.2 *Obesity*

As well as looking at the clinical manifestations of body image in eating disorders, some authors argue for an integrated approach which considers a range of eating and weight-related difficulties that may be identified in eating disorder patients and people classified as overweight/obese (Sánchez-Carracedo et al., 2012; Wilksch et al., 2014). The prevalence of obesity in eating disorder cases was predicted to be around 28.80%, which has increased in the past decade and has been associated with higher psychopathology and disordered eating severity (Villarejo et al., 2012). Obesity and eating disorders have been found to share common risk factors such as dieting, media usage, body dissatisfaction, weight concerns, and weight-related teasing, suggesting that an integrated approach to understanding both may be beneficial (Haines & Neumark-Sztainer, 2006; Neumark-Sztainer et al., 2007). Evidence indicates that obese women experience negative body image (Schwartz & Brownell, 2004; Weinberger et al., 2016) and commonalities between disordered eating for weight loss and obesity have been identified, as they are both associated with dieting, decreased quality of life (i.e. a constant battle with weight) and negative feelings related to weight (Couch et al., 2016).

Globally, there has been an increase in the percentage of the population that have BMIs in the obese range since the mid-1900s (Ogden et al., 2007; Twells et al., 2014). This has both societal and individual level implications, including negative health outcomes and a strain on public health resources (Flegal et al., 2005; Swinburn et al., 2011). Health Survey for England (HSE) data from 2018 reports an increased in the prevalence of obesity (BMIs $\geq 30kg/m^2$) since 1993, particularly for women, and a 2.9-fold increase in severe obesity (BMIs $\geq 40kg/m^2$). The statistics indicate that 59.70% of women aged 16 and above are overweight/obese, with 29.20% categorised as obese (see Figure 1.1 for the percentage of adults in each BMI category; HSE, 2018). Overweight/obesity is lowest for adults aged 16 – 24 and tends to increase with age (Figure 1.2). In Lincolnshire, where the majority of the research in this thesis was conducted, a report from 2018/19 stated that 66.50% of adults in Lincolnshire had BMIs classified as overweight/obese (Public Health England, Public Health Profiles, 2020), though no sex-specific values are reported.

Figure 1.1

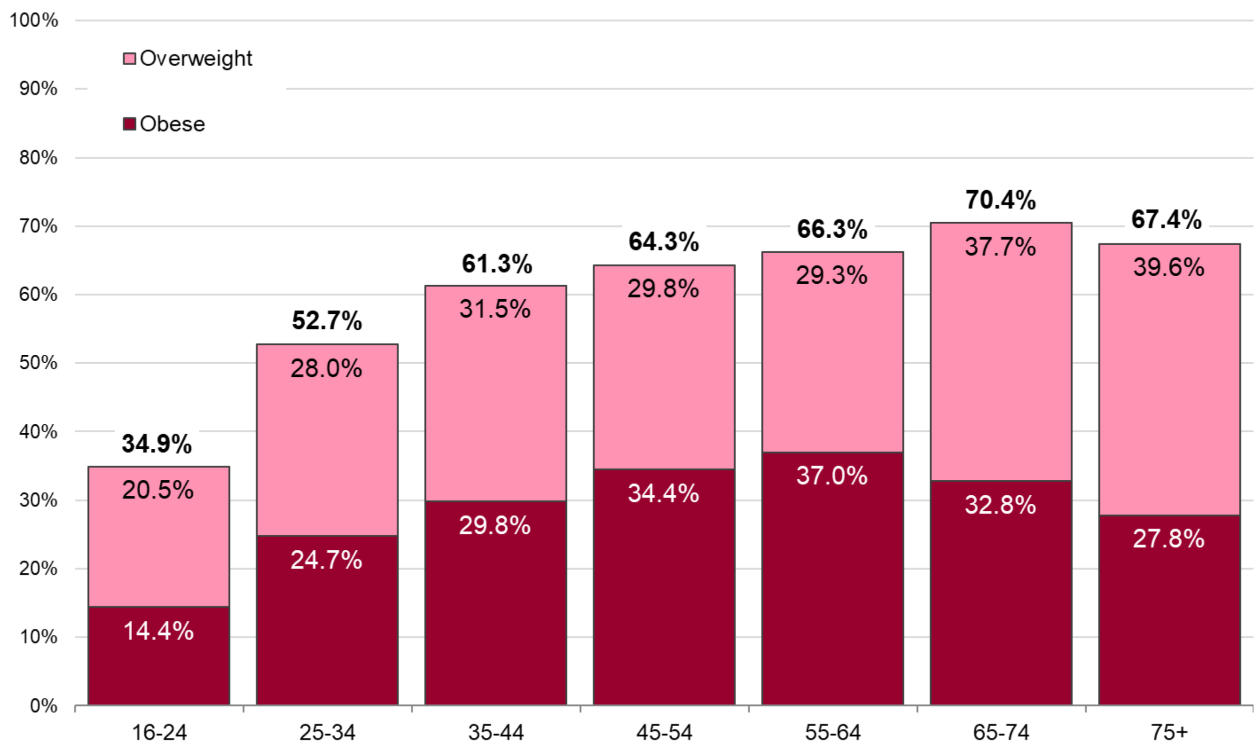
The BMI distribution of male and female adults aged 16 and over in the UK, according to HSE 2018 data. Taken from Public Health England (2020).



Note. Underweight: < 18.5 kg/m^2, Healthy weight: 18.5 to < 25 kg/m^2, Overweight: 25 to < 30 kg/m^2, Obese: ≥ 30 kg/m^2.

Figure 1.2

Overweight/obesity per age group, for women, according to HSE 2018 data. Taken from Public Health England (2020).



1.4 Body Size Misperception across the BMI Spectrum

Accuracy of self-perceived body size/shape estimation has been associated with the individual's actual body size/shape. Women classed as overweight/obese by BMI tend to underestimate their body size when categorising themselves according to BMI or weight status labels (e.g. underweight, normal weight, overweight, and obese) (Gregory et al., 2008; Truesdale & Stevens, 2008), although, research suggests that underestimation is more common in men than women (Freigang et al., 2020; Gardner, 2014). In addition to underestimation of higher BMIs, research indicates those with lower BMIs overestimate their body size, for both healthy control and eating disorder patients (Cornelissen et al., 2015; Cornelissen et al., 2013). Evidence suggests that under-/normal weight women are more likely to overestimate than men, using categorical labels and visual estimates (Chang & Christakis, 2003; Gardner et al., 2009; Kuchler & Variyam, 2003; Nissen & Holm, 2015). There appears to be a modulating effect of psychological state, where those with increased weight concerns and negative affect tend to overestimate more (Cornelissen et al., 2015; Cornelissen et al., 2013), though it does not fully explain the pattern of the results suggesting that inaccuracies may be primarily explained by perceptual factors.

These findings extend to judgements made about other people's bodies, where the body size/shape of the body being judged influences estimation accuracy. For example, research investigating parent's perceptions of their child's body weight indicates that underestimation of overweight/obesity is common (e.g. Black et al., 2015; Jones et al., 2013; Lundahl et al., 2014; Rietmeijer-Mentink et al., 2013). Similar patterns exist for judgements of other adult bodies, where overweight/obese bodies are often underestimated and perceived as lower in BMI than they actually are, using categorical labels and visual estimates (e.g. Cornelissen et al., 2016; Gledhill et al., 2019; Oldham & Robinson, 2016, 2017). This has implications for healthcare, where a range of healthcare professionals tend to be inaccurate in their visual estimations of patient weight status (Ahern et al., 2012; Robinson et al., 2014; Yoong et al., 2013). Like self-estimates, obese male bodies are typically underestimated more often than female bodies (Oldham & Robinson, 2017; Yaemsiri et al., 2011). Previous work has used predominately or exclusively female samples making judgements about other same-sex bodies, where low-normal BMI bodies were overestimated and overweight bodies were underestimated (e.g. Gledhill et al., 2019), or opposite-sex judgements, where overweight/obese male bodies were underestimated (e.g. Oldham & Robinson, 2016). Oldham and Robinson (2016) did not find any effect of observer sex on BMI category accuracy for male bodies, whereas Robinson and Hogenkamp (2015) did find higher same-sex accuracy for overweight/obese male bodies. Vartanian et al. (2004) found sex differences in estimates of female body weight, in that males were more likely to underestimate than females. They argue that opposite sex judgements may be a factor in visual inaccuracies due to a lack of point of reference.

Using photographs of women varying in BMI, there is evidence of misperception for same-sex judgements. Findings from Vartanian and Germeroth (2011) indicated significant overestimation of underweight bodies and underestimation of normal, overweight and obese bodies, which was not significantly related to the observer's weight or level of dietary restraint in a sample of female undergraduate students. However, Tovée et al.'s (2000) findings suggest that the BMI of the observer, but not psychological concerns, modulates perceptual accuracy for one's own and others body size, for AN/BN patients and controls. On the other hand, significantly higher weight estimates for eating disorder patients than controls have been demonstrated (e.g. Horndasch et al., 2015; Moody et al., 2017), though the overall pattern of findings across the BMI spectrum seems to be consistent (George et al., 2011). Gledhill et al. (2019) found that both AN patients and controls overestimated low-normal BMI bodies and underestimated overweight bodies. They found a marginally significant effect of group, such that AN patients overestimated body weight slightly more than controls. For both groups, estimates were modulated by psychological concerns - higher disordered eating symptomology resulted in a greater magnitude of error. These findings demonstrate substantial evidence for inaccurate perceptions of body size (for self and others) across the BMI spectrum, which is largely related to the actual size of the body, with some modulation from psychological concerns and inconclusive findings regarding observer sex and BMI.

1.4.1 *Perceptual Explanations of Body Size/Shape Misperception*

One possible explanation for the under-estimation and -detection of obese body sizes in Western societies is termed ‘the Visual Normalisation Theory’ (Robinson, 2017). This theory proposes that increases in the proportion of people categorised as overweight/obese has resulted in an upward shift and recalibration of what is considered a normal body size. Burke et al. (2010) argue there has been a generational shift in the perception of a normal body size associated with a rise in obesity, in that from early 1990 to 2000 the underestimation of overweight/obesity has increased in the US. Similar findings are reported by Johnson et al. (2008) in the UK from 1999 to 2007. In this norm-based theory, only body sizes considered above the ‘norm’ would be considered overweight/obese, resulting in the visual under-detection of overweight/obesity (Oldham & Robinson, 2017). This is consistent with evidence indicating that one’s ‘visual diet’ influences body size preferences and perceptions of what is an ‘average’ or ‘normal’ body size, due to a cognitive adaptation induced from increased exposure to particular body sizes (Boothroyd et al., 2012; Tovée et al., 2006). This is supported by cross-cultural research identifying shifts in body preferences associated with changes in visual diet (e.g. exposure to Western media and/or environmental changes) (Boothroyd et al., 2016; Thornborrow et al., 2018; Tovée et al., 2006). Data from several countries suggests that the threshold for where overweight ‘begins’ (marked on a 0 – 100 scale with silhouette figures of bodies from underweight to obese) is linearly related to prevalence (i.e. the percentage of the population that are overweight), for both male and female bodies (Johnson et al., 2015). Several studies have found evidence indicating that exposure to bodies with increased BMI in everyday life (e.g. having peers/family members with higher body weights) and in experimental settings (e.g. exposure to photographs of overweight/obese bodies) is associated with greater underestimation of overweight/obese BMI weight status (Maximova et al., 2008; Oldham & Robinson, 2016, 2017; Robinson & Christiansen, 2014). Robinson and Christiansen’s (2014) findings suggest that exposure to overweight/obese bodies increased ratings of the acceptability and healthiness of overweight/obese bodies post-exposure and decreases agreement that the person should lose weight, which the authors argue is linked to a change in visual preference (liking the look of the body size), indicating perceptual and attitudinal components to post-exposure preferences.

Another possible, albeit not mutually exclusive, explanation accounting for inaccuracies in visual body size estimation across the BMI spectrum is a perceptual phenomenon termed ‘contraction bias’ (Poulton, 1989). This explanation posits that an individual uses an internal standard reference as a template for which other examples of that object class are estimated against. Magnitudes smaller than the standard reference are overestimated and magnitudes larger than the standard reference are underestimated (Poulton, 1989). The magnitude of error increases with deviation from the standard reference. This may explain inaccuracies across the BMI spectrum, as estimates of body size closest to the individual’s standard reference will be most accurate and those farther away will be least accurate (overestimation of lower BMI bodies and underestimation of higher BMIs). The standard reference is understood to be based on all the bodies we have seen and influenced by the types of bodies we typically see/are familiar with, weighted towards recent exposure (Leopold et al., 2001; Rhodes et al., 2013; Winkler & Rhodes, 2005). Again, indicating influence from one’s ‘visual diet’. For example, one study found that exposure to underweight bodies resulted in a decrease in the most normal and ideal body size, whereas exposure to an obese body size increased the BMI of that considered the most normal and ideal (Glauert et al., 2009). Evidence of contraction bias has been found for self-estimates (e.g. Cornelissen et al., 2015; Cornelissen et al., 2013) and estimates of other bodies (Cornelissen et al., 2016; Gledhill et al., 2019).

Another perceptual phenomenon which has been demonstrated to be a factor of body size perception is known as ‘Weber’s law’, which states that the Just Noticeable Difference (JND) (the smallest difference that can be reliably identified between two stimuli) will be a constant proportion of stimulus magnitude (Gescheider, 1997). For body size, this means that the JND will increase as body size increases at a constant proportion (e.g. one BMI unit difference between two low BMI bodies would be easier to detect than one BMI unit between two high BMI bodies). This has been demonstrated in empirical research using two CG body models calibrated to increase linearly in BMI (Cornelissen et al., 2015; Cornelissen et al., 2018; Cornelissen et al., 2016). In patients with Anorexia Nervosa Spectrum Disorder, Cornelissen et al. (2015) found that those with low BMIs (< 17.50) were accurate at estimating their body size and were sensitive to changes (small JND), however as their BMI increased there was evidence of overestimation of body size and decreased sensitivity. The JND tends to be unrelated to psychological concerns, for example, Gardner and Bokenkamp (1996) found no difference in the JND between controls and eating disorder (AN/BN) patients and Cornelissen et al. (2015) found no relationships between the JND and weight concerns or negative affect scores. Together, with contraction bias, these perceptual factors make it harder to detect overweight/obesity and to identify weight changes due to underestimation and decreased sensitivity, but easier for AN patients with low BMI to detect small weight changes.

Practical Implications. One implication of underestimation and decreased sensitivity to weight change for overweight/obese bodies is regarding healthy weight control and management. In healthcare settings, this may mean that professionals are less likely to initiate discussions regarding weight management and may impede intervention (Robinson et al., 2014). Some research suggests that desire and pursuit of weight control were predicted by self-perception of overweight/obesity and a diagnosis by a healthcare professional (Yaemsiri et al., 2011).

Moreover, the accuracy of judgements of other female's bodies may be involved in social comparison processes, where a female compares her body to others, which may contribute to disordered eating behaviours and body image concerns (Griffiths et al., 2016; Morrison et al., 2004). Comparisons to peers and models has been linked to body dissatisfaction (Jones, 2001; Myers & Crowther, 2009; Tiggemann & Polivy, 2010). If low/normal BMI bodies are overestimated, this may result in unrealistic perceptions of a normal body size, which can be detrimental when self-comparisons are made.

Self-identification of overweight status has been associated with adverse implications for mental health and wellbeing (Robinson et al., 2017). Irrespective of accuracy, perceived overweight status was associated with greater use of weight loss/control strategies and weight gain over time (Feng & Wilson, 2019; Haynes et al., 2018), and decreased self-reported health and increased depressive symptoms at a 7-year follow up (Daly et al., 2017). This may partly be attributed to the stigma, biases, and prejudice that individuals with obesity experience (Puhl & Heuer, 2009; Puhl et al., 2015). Biases also occur for low BMI bodies (Swami et al., 2008; Swami et al., 2010). Some research suggests that there was bias against emaciated (BMIs below 15) and obese bodies in hypothetical occupational, adoption, and helping behaviour decisions (Swami et al., 2010). Swami et al. (2008) found that obese bodies were more likely to be rated as lazy, lonely, and teased, whereas underweight bodies were considered lonely and teased but not lazy. Experiences of weight stigma and internalisation of weight bias have been associated with negative mental health outcomes (Pearl & Puhl, 2018; Puhl & Heuer, 2009), increased BMI, self-perceived body size, and weight-loss efforts (Puhl et al., 2018), and has negative effects on quality of life and self-identity (Ramos Salas et al., 2019). Weight stigma is associated with disordered eating, mediated by weight bias internalisation and psychological distress, in both overweight/obese and non-overweight young adults (O'Brien et al., 2016). Weight bias internalisation predicted eating pathology in under-/normal weight individuals and was increased for those who perceived themselves as overweight/obese and self-categorised as dieting to lose weight (Schvey & White, 2015). It has been hypothesised then that underestimation of self-reported body weight may be a protective mechanism to preserve psychological wellbeing as opposed to a perceptual bias (Polivy et al., 2014). This may be one potential factor that modulates underestimation of weight, rather than a qualitative difference, and may be most relevant to reports of weight/category labels than visual estimations. Nonetheless, together this evidence provides compelling evidence for adverse effects on physical, psychological and social wellbeing associated with weight stigma and the stress associated with identifying as part of a stigmatized group.

Body image distortion is a key feature of eating disorders (Cash & Deagle, 1997; Farrell et al., 2005; Hagman et al., 2015), which has implications for treatment and recovery. In women with AN spectrum disorder, there is evidence of increased overestimation and decreased sensitivity to body size changes as BMI increases, which could result in relapse behaviours (Cornelissen et al., 2015). For AN inpatients, overestimation was related to progress after discharge and likelihood of relapse (Slade & Russell, 1973) and body image disturbance differentiates partially and fully recovered patients (Bardone-Cone et al., 2010). Consequently, there is a need for developing effective treatments and interventions for body image disturbances and randomised control trials exploring the effectiveness (Sharpe et al., 2018). Body image targeted interventions are being increasingly recognised as effective for treatment (McLean & Paxton, 2019), demonstrating small but reliable improvements when used alone (Alleva et al., 2015). Farrell et al. (2006) proposed incorporating specific treatment of body image disturbances into existing evidence-based interventions and Stice and Shaw (2002) concluded that placing more emphasis on body image disturbances would be beneficial for future interventions.

Some researchers, such as Tovée et al. (2000) and Moody et al. (2017), argue that treatments could target general overestimation of weight, not just perceptions specific to the individuals own body, to directly address disturbances in the perceptual component of body image. One way to do this may be using visual adaptation techniques (Brooks et al., 2020) on the premise that aftereffects are not identity-specific (Brooks et al., 2016; Hummel et al., 2012). For example, reducing exposure to thin bodies and increasing the exposure of bodies higher in the BMI spectrum, as regularly viewing thin bodies skews and biases the perception of what is a normal body size towards a thinner body size, resulting in the misperception of others and one's own body size (Challinor et al., 2017). Bould et al. (2018) found that participants with high body dissatisfaction were more likely to perceive their own and other bodies as lighter and were more satisfied after visual exposure to overweight bodies in an experimental task. Although, at a 24-hour follow-up, differences in self-perceived body size were no longer significant, indicating that the lasting effects of exposure techniques may be short. This indicates that using exposure techniques to shift perceptions of a 'normal' body size may alter perceptions of body size/shape, but that the lasting effects may be short, especially for those with increased levels of dissatisfaction.

An intervention using Cognitive Bias Modification (CBM) protocol was developed to manipulate perceptions of thinness (Gledhill et al., 2017). This was adapted from a face training intervention (Penton-Voak et al., 2013), where facial expressions were categorised as either 'happy' or 'angry'. The CBM task used written feedback (e.g. 'correct' or 'incorrect') to either shift (inflationary feedback) or maintain categorisations. The findings indicated that the categorical perception of facial expressions could be manipulated using the inflationary feedback and that modifications were associated with positive psychological outcomes e.g. reductions in aggressive behaviour and state anger, lasting for up to two weeks. The authors conclude that this

CBM task may be clinically applicable as a simple, fast, and cost-effective technique to reduce aggressive behaviour. These CBM techniques were originally developed in the treatment of anxiety, which demonstrated promising clinical and therapeutic efficacy, corroborating the clinical utility of such approaches (see e.g. Hakamata et al., 2010). Following Penton-Voak et al.'s (2013) protocol, Gledhill et al. (2017) used Computer-Generated (CG) bodies varying in BMI which were to be categorised as either 'thin' or 'fat'. To determine the range of BMI necessary, Gledhill (2015) asked a sample of female participants to categorise bodies as either 'thin' or 'fat', to identify those that were consistently rated the same way 100% of the time (i.e. categorically considered 'thin' or 'fat'). It was found that bodies with a BMI of below 17 were consistently categorized as 'thin' by all respondents and bodies with a BMI of 28 and above were consistently categorized as 'fat', so a range of stimuli that exceeded these limits was used. During the CBM protocol, each participant's categorical thin/fat boundary was calculated; the point where bodies were no longer categorised as 'thin' and were categorised as 'fat'. Based on the boundary, written feedback was used to either shift the perception of 'thin' higher up in the BMI spectrum so that fewer bodies were considered 'fat' post-training (inflationary feedback) or consistent with the categorical boundary to maintain existing categorisations (control), on four consecutive days.

In women with high body concerns, Gledhill et al. (2017) found that for those receiving inflationary feedback in the intervention condition, fewer bodies were perceived as 'fat' post-intervention and this was maintained at a two-week follow-up. There were also improvements in psychological outcomes post-intervention to within age-matched norms on the EDE-Q and significant decreases in eating disorder psychopathology and body dissatisfaction. Using a narrower range of stimuli from underweight to normal weight (14.40 - 24.40 BMI units), Szostak (2018) found that the intervention significantly modified participants categorical boundary and body satisfaction, which was maintained at a two-week follow-up. However, both the intervention and control groups showed decreases in drive for thinness and bulimic symptoms at the two-week follow-up. The most ideal and attractive BMI for the intervention group was significantly higher at follow-up, suggesting a change in body size ideals. For the control group, there was no significant change in the most ideal body size, but there was a significant decrease in the most attractive BMI. Irvine et al. (2020) applied the intervention in an immersive Virtual Reality (VR) environment. There were significant increases in categorical boundary and decreases in eating and body image concerns, which were maintained at the two-week follow-up for the intervention group. Together these findings suggest that this CBM task can successfully manipulate the categorical perception of body size for up to two weeks, with improvements in psychological concerns related to body image and disordered eating and altered perceptions of ideal/attractive body size.

1.5 Methodology: The Assessment of Perceptual Body Image

Perceptual body image has been assessed using various techniques which can be broadly categorised into two categories: i) metric - body-part and ii) depictive - whole-body (Skrzypek et al., 2001). Using these techniques, perceptions of current and ideal body size/shape are typically assessed, which can then be used as a proxy for body image distortion (BID; the discrepancy between perceived and actual body) and perceptual body dissatisfaction (BD; the discrepancy between perceived and ideal body). Below, the techniques and findings using each method are summarised and discussed.

1.5.1 *Metric – Body-Part Size Estimations*

One metric method is the ‘moveable calliper technique’ where participants adjust the distance between two callipers to match the width of different body-parts (Slade & Russell, 1973). Another is the ‘adjustable light beam apparatus’ (Thompson & Spana, 1988; Thompson & Thompson, 1986) where lights projected onto a wall must be adjusted to match the width of different body-parts. The ‘image marking procedure’ (Askevold, 1975) involved imagining one’s self in the mirror and marking where body-parts would be on the wall in front. The width of the body-part estimates can be measured and compared with the actual body-part width. These techniques often show inconsistent results regarding BID in AN (Smeets et al., 1997) and only tells us about the perceived width of a body-part, failing to tap into holistic processing of how one perceives their overall body size/shape.

Some techniques allow the manipulation of particular body-parts whilst simultaneously altering overall body size/mass; made viable by computer programs and technological improvement. This is beneficial as distortion and dissatisfaction of both body-parts and overall body size/shape can be assessed (Letosa-Porta et al., 2005). Tovée et al. (2003) used morphing software where the size of different body-parts (e.g. arms, thighs, calves, chest, hip etc.) on an individual’s photograph could be altered using slider adjustments. The adjustments mimic increases/decreases in fat on those areas, based on photographs and anthropometric data collected from a sample of 213 Caucasian women, which is more ecologically valid than body-part width estimations (see Benson et al., 1999). The BMI of the participant’s estimations could then be calculated using the perimeter-area ratio equation, where the area within the perimeter of the body figure is divided by the path length around the perimeter (Tovée & Cornelissen, 1999; Tovée et al., 1999). The results from Tovée et al. (2003) show that controls and eating disorder (AN and BN) patients were accurate at estimating their overall body, though patients showed slightly greater overestimation than controls. The controls overestimated their chest and waist size compared to the other body-parts, whereas AN and BN patients did not show significant differences in accuracy between body-parts. All groups showed a trend for desiring a smaller ideal body size, which was significantly lower in BMI than perceived and actual for controls and BN patients, and all groups desired smaller waist and thigh sizes. Another method is the use of an interactive 3D modelling software e.g. Daz Studio (Daz3d.com), where a 3D CG model can be manipulated to vary in size and shape using whole-body and body-part specific sliders. The models can be scaled to a selected height so that measurements can be taken (in centimetres) that represent the dimensions the body would have if it was real, and BMI can be estimated using the volume of the shape (Crossley et al., 2012) or HSE calibration curves (Thornborrow et al., 2018), allowing for information of body shape and overall size. This method has been shown to have good test-retest reliability (Crossley et al., 2012) and analysis of body ideals revealed correspondence between men and women's ideal body size/shape, such that both sexes desire a female body with a low-normal BMI with a curvaceous shape, and a male body with a BMI on the boundary of normal to overweight with a V-shaped upper body. These approaches may be a suitable alternative, as more information about body size/shape is captured than just perceived width.

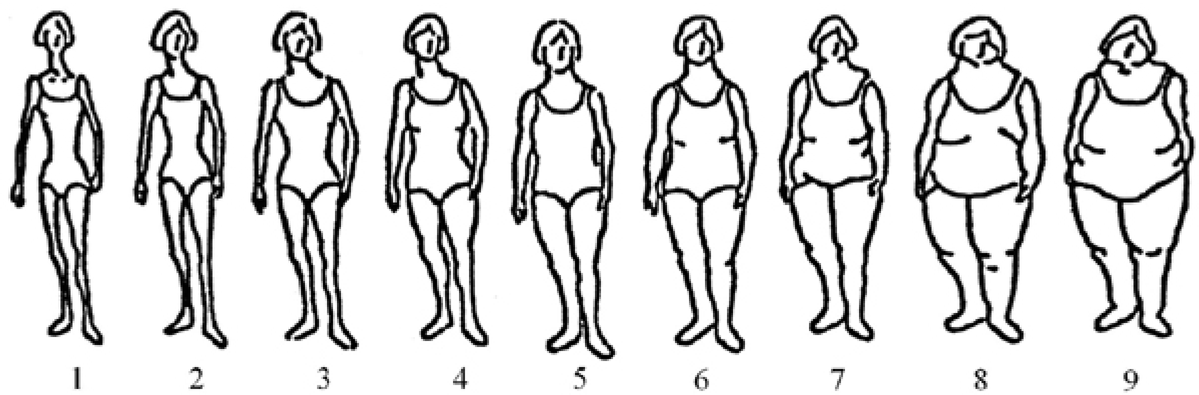
1.5.2 *Depictive – Whole Body Size/Shape Estimations*

Figural Rating Scales (FRS). Figural Rating Scales (FRS) are a commonly used visual assessment of overall body size/shape. These scales often contain seven to nine silhouette figures or line drawings of bodies varying in body size (Gardner & Brown, 2010a; Gardner et al., 1998) from 'thin' to 'fat' (Grogan, 2016). They provide a fast, simple, and mostly non-verbal approach to understand perceptions of body size/shape and may be used across a variety of samples and settings (Grogan, 2016). An abundance of FRS have been created, Thompson and Gray (1995) reviewed 22 and many did not demonstrate sound psychometric qualities. Stunkard (2000) recommends that the reliability and validity of new scales should be demonstrated to be better than the ones currently being used.

A popular scale is the Stunkard Figural Rating Scale (SFRS) (Stunkard et al., 1983) which consists of nine body silhouettes increasing in size from thin to obese (Figure 1.3). Bulik et al. (2001) determined optimal cut-offs, where figure 4 and below captures 'thinness' (BMI < 21) and figure 6 and above captures obesity (BMI > 30). This scale has been shown to have good test-retest reliability (Banasiak et al., 2001; Gardner & Brown, 2010a), construct validity (selections of current body size correlated with the person's weight and BMI) (Gardner et al., 1999), and accuracy when judging other females body size through video and in-person (Cardinal et al., 2006). The SFRS is considered a valid measure of BD as discrepancies between perceived and ideal selections correlate with attitudinal measures of body dissatisfaction, eating disturbances, and self-esteem (Altabe & Thompson, 1992; Thompson & Altabe, 1991). Although, this scale may be criticised for the use of artistic impressions which tend to subjectively represent a variety of body sizes rather than known body measurements for each body size (Gardner & Brown, 2010a). Gardner et al. (1998) and Gardner et al. (1999) highlight that there are disproportionate changes in weight for different body-parts across the scale and variations in height, with no evidence of whether this reflects actual weight change. This reduces the ability to compare to the participant's actual body size/shape to assess BID (Gardner & Brown, 2010a).

Figure 1.3

Female images of the SFRS (Stunkard et al., 1983).



Some silhouette scales have been developed based on known anthropometric measurements to provide a more accurate representation of body size/shape. For example, the nine-figure Contour Drawing Rating Scale by Thompson and Gray (1995) was based on realistic changes in Waist-to-Hip Ratio (WHR), which were 'critiqued for subtlety, consistency and accuracy in incremental body sizes changes'. The authors found that this scale had good construct validity and test-retest reliability in a sample of undergraduate students. Using this scale, Zaccagni et al. (2020) found that women desired a smaller ideal body size and selections of perceived body size correlated with their actual body fat, though responses were limited to a subsection of images and the extremes were not used. The Body Image Assessment-Body Dimensions scale by Gardner et al. (2009) was based on anthropometric body dimensions (shoulder, chest, waist, hip, thigh, and upper leg breadth) from thousands of people in the US Air Force. This scale consists of 17 figures ranging in weight from 60% below the average weight to 140% above average, which corresponds to BMIs from 19.92 to 39.48 (calculated using weight values for each body and the average height). There are consistent changes of 5% weight between adjacent bodies, corresponding to approximately 1.40 BMI units. This scale showed good construct validity and test-retest reliability for perceived current body size and perceptual BD

(Gardner & Brown, 2010b; Gardner et al., 2009). Results using this scale demonstrate that women desire an ideal body size smaller than their perceived and actual and tend to overestimate compared to a method of adjustment width-distortion technique using their own photograph (Gardner & Brown, 2010b).

Generally, FRS have been criticised for the reliance on line-drawings and artistic impressions, which are not realistic or ecologically valid depictions of human bodies (e.g. missing facial features - eyes and mouth, poorly defined body features, and disproportionate body parts) (Thompson & Gray, 1995). Some authors contend that removing all appearance-related features is beneficial as it means that the participant's attention is focused purely on body size and shape (Gardner et al., 2009), although such minimal detail may limit identification with the stimuli. Methodological concerns with presenting the bodies in ascending order have been raised, particularly when there is a limited number, as it could inflate test-retest reliability and result in inaccurate/untrue responses due to scale coarseness (Gardner et al., 1998). Holder and Keates (2006) found that presenting figures picture-sized resulted in larger estimations of body size compared to life-sized, which may indicate that the size of presentation may be contributing to estimation inaccuracies.

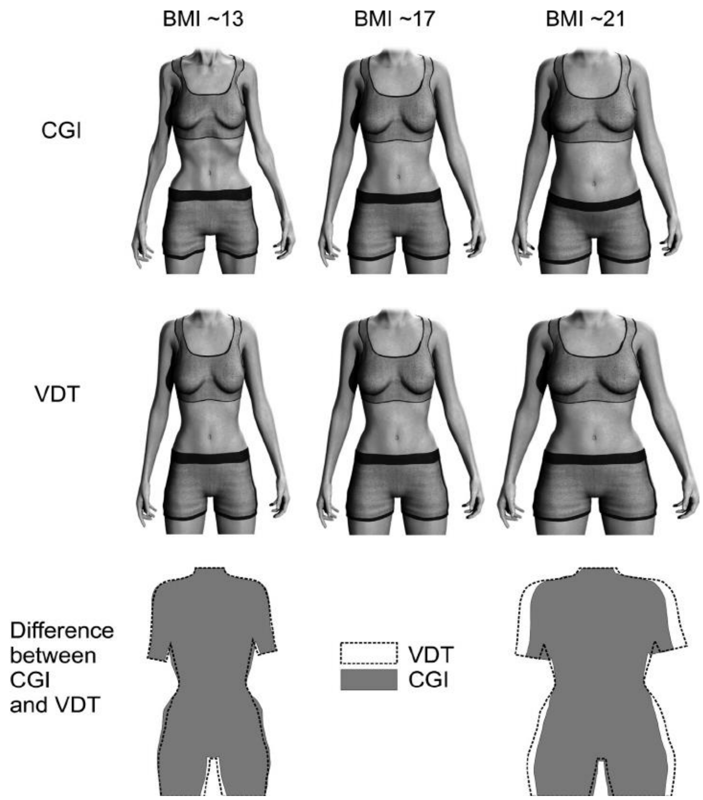
Width Distortion. The Video width-Distortion Technique (VDT) involves the manipulation of an individual’s photograph in the horizontal plane, such that increased width corresponds to a larger or ‘fatter’ body size and decreased width corresponds to a smaller or ‘thinner’ body size. Using the VDT, participants are presented with a recording of the width-distorted versions of their body and are asked to use a controller to indicate their perceived/ideal size. Discrepancies between perceived and actual width can be used to identify evidence of BID (Allebeck et al., 1976). Using the VDT, results from Touyz et al. (1984) indicate that healthy controls and AN patients were accurate on average. Both groups desired a significantly smaller ideal body size than their perceived, indicating dissatisfaction with their current body size. Findings by Probst et al. (1992) suggest that both control participants and AN patients underestimated their body size slightly and had an ideal body smaller than their actual size, although the discrepancy was more pronounced for the control participants. Another study by Sand et al. (2011) asked adolescents to manipulate the width of photographs using ‘shrink’ and ‘stretch’ buttons to assert self-perceived body size, estimates of others body size (based on photographs of an adolescent boy, girl and a female adult assistant) and a neutral object (milk carton). Their findings indicate that those with higher eating disorder symptomology significantly overestimated their body size, compared to those with low symptomology. There were no differences for their perceptions of other adults and the neutral object, where the size of other adolescents was overestimated and the female adult research assistant and neutral object were slightly underestimated. Other predictors of self-overestimation included overestimation of same-sex peers and the neutral object, high drive for thinness, and lower self-esteem.

Distortion techniques have been adapted to be used on a life-sized screen. Probst et al. (1995) found that both eating disorder patients and controls accurately estimated their body size when taking into account the JND (+/- 5%), although accuracy was slightly better for controls. Participants generally desired a smaller ideal body size. Similar findings from Probst, Vandereycken, Van Coppenolle, and Pieters (1998) indicate that AN patients were generally accurate; around 20% demonstrated clear overestimation, which was associated with negative body image and a more neurotic psychological profile. Gardner and Bokenkamp’s (1996) results suggest that AN and BN patients overestimated indicate their whole body and individual body parts (chest, stomach, and hips – determined by blocking off the rest of the body during presentation), significantly more than control participants who tended to be accurate. Shafran and Fairburn (2002) adapted this technique by photographing participant’s looking at themselves in a full-length mirror and width-distorted images were projected to be life-sized, to create a more ecologically valid approach. Eating disorder patients overestimated significantly more than controls and both groups desired an ideal body smaller than their own.

Probst et al. (1995) state that the reliability of the VDT, particularly on a life-size screen, is good. Estimates using this technique correlated with FRS estimates and cognitive-affective responses (Probst, Vandereycken, Vanderlinden, & Van Coppenolle, 1998; Shafran & Fairburn, 2002), suggesting that it is both a reliable and valid measure of perceptual body image. Sand et al. (2011) state that the individualised component of this technique is advantageous compared to standardised FRS. However, the ecological validity of VDT may be disputed as it is based on manipulating body images in the horizontal plane, so it does not depict realistic weight gain or body fat storage with increasing size or weight loss with decreasing size. The VDT is a linear method which results in unrealistic body shape changes, particularly in the shoulder and hip regions where the width is exaggerated as BMI increases (Cornelissen et al., 2015). Comparison of width-distorted and CG models calibrated for BMI are presented in Figure 1.4, demonstrating how the VDT does not result in accurate depictions of body size/shape changes.

Figure 1.4

The difference in body shape at different BMIs for width-distortion models compared to computer-generated models calibrated according to national statistics. Taken from Cornelissen et al. (2015).

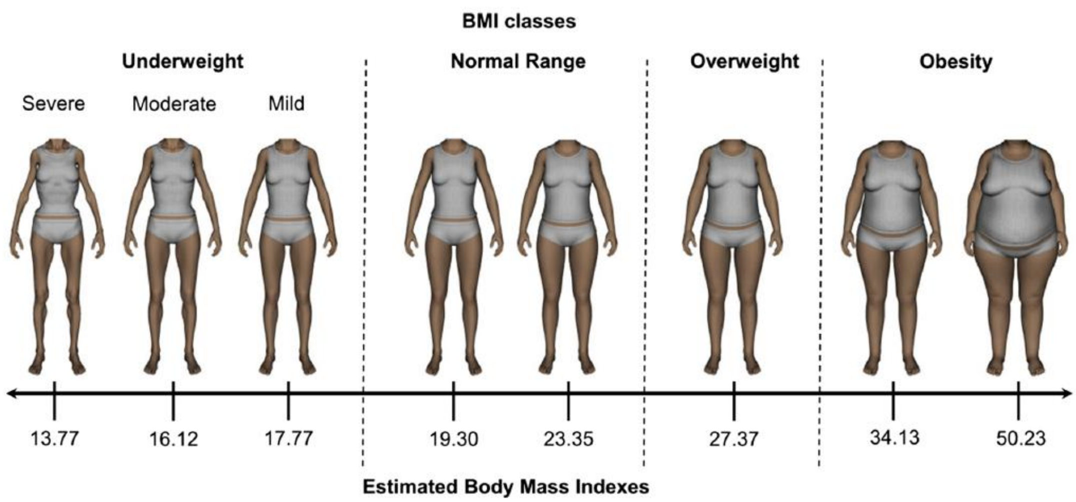


Computer-Generated Imagery (CGI). The use of CGI to create body stimuli has become increasingly utilised due to advancements in technology and the advantages associated with the technique, including ecological validity and realism, ease of capturing weight extremes (models can be manipulated to capture very low and high body sizes), standardisation/homogeneity across images (controlling for extraneous factors such as skin colour, texture, lighting etc.), and more accurate/realistic changes in body shape as BMI changes (demonstrated in Figure 1.4, see also Alexi et al., 2019; Cornelissen et al., 2015; Cornelissen et al., 2017).

A database of 61 CGI female bodies, ranging from severely underweight to obese, was developed by Moussally, Rochat et al. (2017). The stimuli were rated for valence (a combination of attractiveness, beauty and harmony ratings) and body size (thinness - fatness). The body size ratings suggest that body size manipulations were correctly perceived i.e. bodies lower in weight, using the thin morph, were perceived as ‘thinner’, and bodies higher in weight, increased using the heavy morph, were perceived as ‘fatter’. A 27-item Computer-Generated Figural Rating Scale (CGFRS) (12.69 – 69.56 BMI units) was developed using these stimuli (Moussally, Grynberg, et al., 2017), examples of eight figures (one in each BMI class) are presented in Figure 1.5. The findings suggest that around one-third of control participants could accurately estimate their body size (within +/- 1 BMI units), whereas almost half overestimated their body size, and approximately 72% desired a lower BMI ideal. Eating disorder patients showed greater overestimation of size and had a significantly lower ideal BMI than controls. Plausibility ratings indicated good plausibility for mildly underweight to overweight bodies, with bodies at the extremes rated as less plausible. Bodies could be correctly categorized (higher than chance) according to BMI categories by control participants and eating disorder patients; the most errors were for bodies on the category boundaries and most mis-categorisations were by one category. Test-retest reliability was moderate to strong and construct validity (correlations with cognitive-affective measures) was good. These findings suggest that CG stimuli may be a valid, reliable and accurate way to assess perceptions of body size/shape, in future work. This method avoids some of the issues with existing measures, such as low-quality images and inaccurate representations of body shape change.

Figure 1.5

Examples of CG stimuli used in the Computer-Generated Figure Rating Scale, taken from Moussally, Grynberg, et al., 2017.



A CGI stimulus set based on HSE data to represent the average Caucasian woman's (aged 18 – 45) body shape and height was developed by Cornelissen et al. (2015). Similarly, to Moussally, Rochat et al. (2017), full-body morphs were used to linearly increase/decrease the body size of a CG model. Using the waist and hip measurements, each models' BMI was calculated using calibration curves from HSE data (Cornelissen et al., 2009). These stimuli are full body and standardised (i.e. same pose, lighting, clothing, skin texture etc.) so that the only change is the BMI (varying from 12.50 – 44.50). To check the plausibility, the stimulus set was compared to a statistical model of the relationship between BMI and 3D body shape in 114 real bodies and photographs of 220 women varying in BMI (Cornelissen et al., 2015). Whilst the shape of a standard model may not be suitable for everybody, researchers suggest that CG body models may mean that participants can more easily project themselves onto the bodies, which may not be the case when using photographs of real but unfamiliar people (Moussally, Grynberg et al., 2017). Such models have been used in a variety of research, including a body size perception intervention (Gledhill et al., 2017), body size discrimination tasks (Cornelissen et al., 2016; Cornelissen et al., 2018), body size estimation tasks (Cornelissen et al., 2017; Cornelissen et al., 2015), and eye-tracking studies (Cornelissen et al., 2016).

Whilst there are robust benefits of using CGI body stimuli, some findings suggest that females found it hard to discriminate between body sizes at the weight extremes when using same-sex CGI stimuli (Alexi et al., 2019) and that perceptions of size were non-linear unlike findings using photographs (Alexi et al., 2018), implying that they may not be processed in the same way. The reasoning behind this is unknown but may be due to a lack of visual realism, a reduction in weight cues (e.g. cellulite and visible emaciation), stimulus ambiguity/lack of familiarity, or the inability to self-compare (Alexi et al., 2019). These stimuli were based on replicating a database of photographs of real-adults (mimicking the clothing, pose, and appearance of each image – see Figure 1.6), meaning that they were not standardised (i.e. each had different poses, clothing, and skin tones) unlike stimuli by Moussally, Rochat et al. (2017) and Cornelissen et al. (2015). The images were also lower quality, which reduces the realism and visibility of weight-related cues. Research using standardised models found that CG bodies are judged the same way as real bodies, for example, Tovée et al. (2012) found that body attractiveness ratings of CG models followed a similar pattern to judgements using photographs, and Cornelissen et al. (2016) found evidence of Weber's law using two different CGI BMI calibrated models and photographs of women varying in BMI, suggesting that CGI is a viable alternative for body stimulus creation.

Figure 1.6

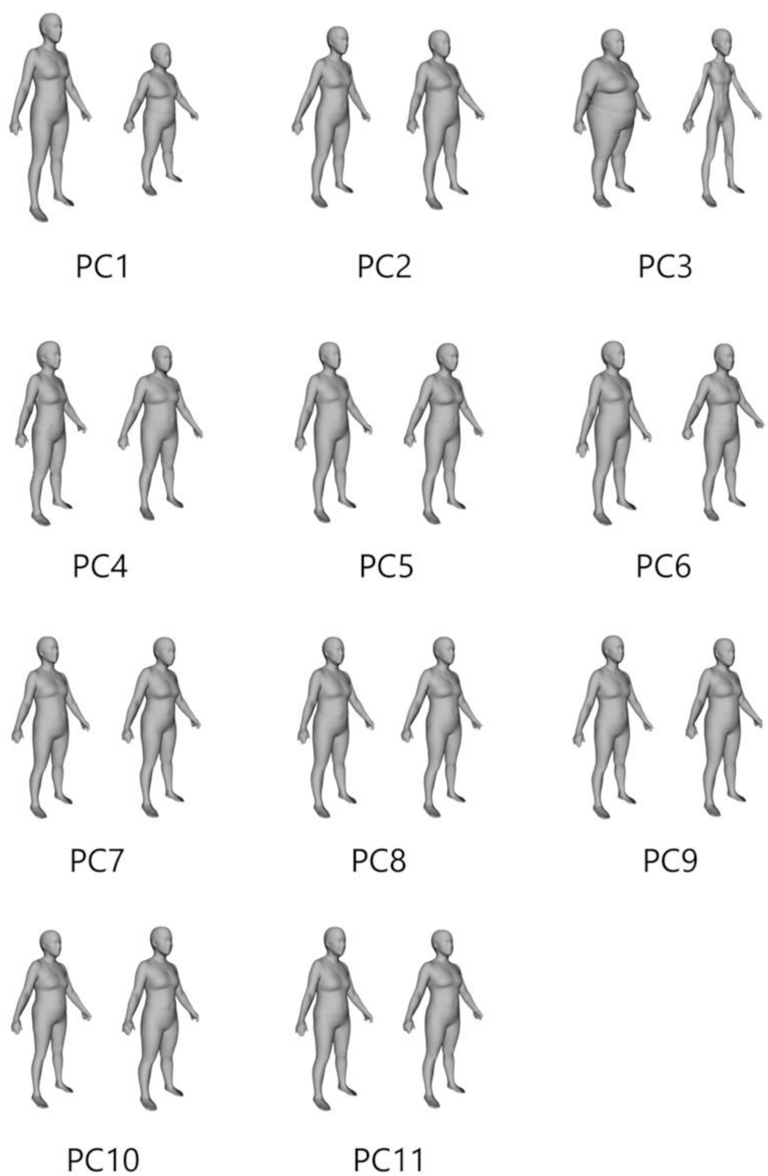
An example of the CG body stimuli used by Alexi et al. (2019) created using Poser, Version 11.

Three-Dimensional (3D) Scanning Technology. There has been an increase in the availability and accessibility of modern 3D scanning technology. This technology enables the area, volume, and anthropometric measurements of a body shape to be accurately captured (Carter & Stewart, 2012; Garlie et al., 2010; Heymsfield et al., 2018; Robinette & Daanen, 2006). Subsequently, it is being used more frequently in body image research and applied clinical and healthcare settings (e.g. monitoring changes in body size/shape, obesity treatment, and providing epidemiological information) (Treleaven & Wells, 2007). Scanners may be considered a non-invasive and quick method for capturing high-quality representations of the human body, due to the use of cameras and light-sensitive devices which do not require physical contact with the body (Carter & Stewart, 2012; Heymsfield et al., 2018). Stimuli generated from scans can be presented in 2D and in VR, making it a good tool for research. Findings from Stewart et al. (2012) indicate good acceptability and engagement amongst eating disorder patients and control participants and no association between self-reported anxiety from scanning and body dissatisfaction. To date, some large databases of 3D scans associated with anthropometric information have been created and used for research purposes, however, there are issues concerning privacy and access which prevent them from being open access and useable by a range of researchers (Daanen & Psikuta, 2018). One example is the Civilian American and European Surface Anthropometry Resource Project (CAESAR) dataset, which is a commercially available database with approximately 13,000 scans from 4,400 individuals aged 18 – 65 years old, each associated with anthropometric and demographic details such as age, sex, ethnicity, height, weight, and a variety of circumference and calliper measurements (Harrison & Robinette, 2002; Robinette et al., 2002).

Principal Component Analysis (PCA) can be used to explore variation in body shape captured using 3D scanning technology (Daanen & Psikuta, 2018). The Principal Components (PCs) can be used to visualise 3D body shape variation at different standard deviations (Pishchulin et al., 2017) and links between PCs and body measurements can be determined using correlations. Ter Haar et al. (2013) used PCA to investigate inter-individual differences in body shape from 200 male and 200 female 3D body scans, with arms removed due to a lack of standardisation. They found significant correlations between the three PCs and body measurements (height, hip and waist circumferences, and inner leg length) and significant differences between males and females on each of the PCs. Similarly, Ng et al. (2019) correlated 11 PCs (capturing 95% of the variance in body shape) with body measurements from a sample of 407 adults (230 females). The results suggest that the first PC captured overall body size and height, whilst the third PC captured thinness/thickness and correlated highly with body measurements such as BMI, waist/hip/arm/thigh circumferences, fat mass, and lean mass, but not height. Stepwise regressions were then used to predict body measurements from the PCs, with results indicating that 3D shape could significantly predict measurements with high accuracy. Figure 1.7 presents the predicted shapes for each PC for the female bodies. Together, these examples demonstrate how 3D body shape captured via scanning technology combined with PCA can accurately capture body composition and be used to model shape variation. These studies allow us to deepen our understanding of how body shape varies and relates to body size/shape/composition, but they do not allow direct comparisons to individuals for assessment of self-perceived/ideal body shape in research or healthcare settings.

Figure 1.7

The 11 PCs capturing 95% of the variance in the females' body shape, displaying +3SD (right) and – 3SD (left) for each PC. Taken from Ng et al. (2019).



A PCA model of 3D body shape varying in BMI has been applied in perceptual body image research. For example, Piryankova, Stefanucci et al. (2014) and Thaler, Piryankova et al. (2018) used the PCA BMI model to investigate the influence of stimuli personalisation. The 'individualised avatar' matched the participant's actual body proportions (height, arm length, and inseam) and the 'average avatar' matched the proportions of the average female body but matched the participant's height. Two different textures were applied to both sets of avatars - a checkerboard texture and the individuals own photorealistic texture. The avatars were manipulated to vary in BMI by +/- 20% of the participant's own BMI at 5% intervals. The findings from both studies indicate that body shape did not have a significant influence on accuracy whereas using a photorealistic texture did, as participant's body size estimation accuracy was significantly better using the individualised texture. This was despite women being able to distinguish between individualised and average avatars and reporting greater similarity to the individualised avatars. Another study by Cornelissen et al. (2017) used two CG avatars: an 'individualised avatar' reflecting the participant's body proportions (emulated from their 3D body scan) and an 'average avatar' reflecting proportions of the average female body taken from HSE data. Both avatars had the same photorealistic CG texture. Results using a method of adjustment task (using a slider to increase or decrease the avatars body size to match one's own) suggest that there were no clear differences between the standard and personalized avatars, with both avatars yielding similar results. These findings suggest that 3D stimuli with an average body shape but photorealistic skin texture is suitable for body size perception research.

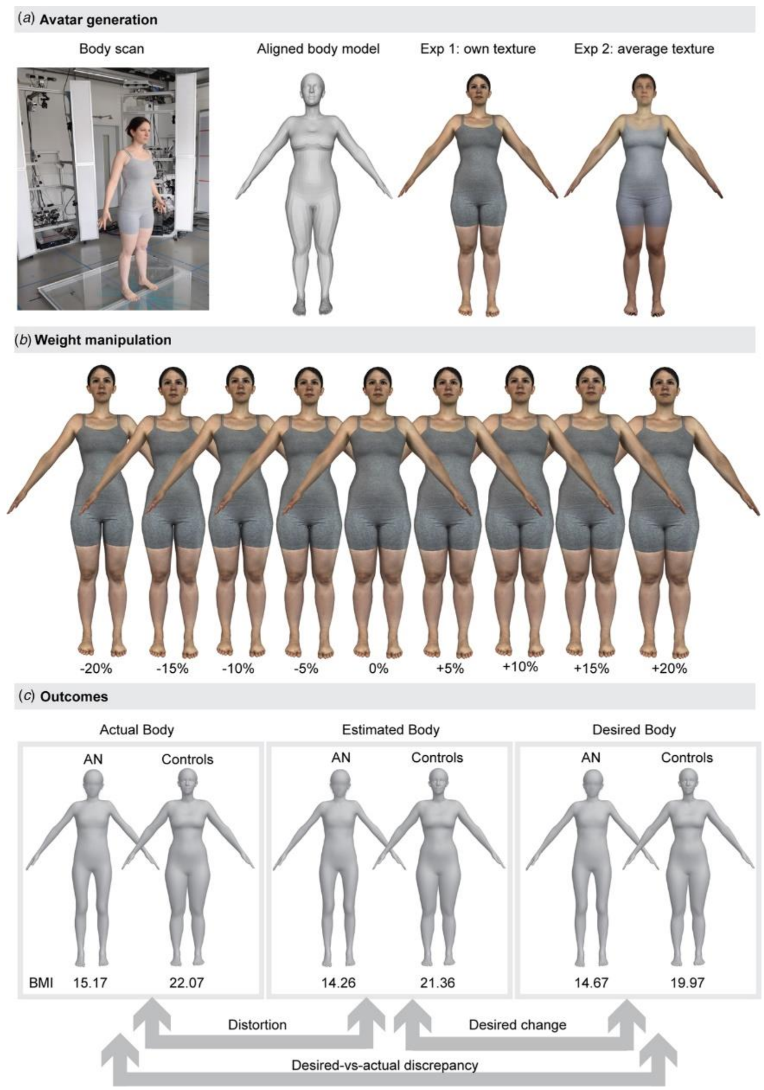
Thaler, Geuss et al. (2018) maintained individualised bodily proportions (arm length, height, and inseam) but varied photorealistic skin texture, to allow comparisons between the individuals own and another woman's identity. Using the same method as Piryankova, Stefanucci et al. (2014) and Thaler, Piryankova et al. (2018) - 3D avatars varying in BMI +/- 20% at 5%

intervals. The findings revealed that participants were fairly accurate in their body size judgements with both identities, however, effects of own BMI for accuracy (underestimation for low-normal BMI and overestimation for higher BMI participants) and sensitivity were specific to the individualised identity. Mölbert et al. (2018) investigated body size perception in AN patients and healthy controls using 3D avatars varying in BMI (+/- 20% at 5% intervals), following the same method as above. They used two different photorealistic textures (the individual's own or an average texture map). Both groups significantly underestimated their body size (though more so for AN patients) when using their own identity, but were accurate when using the average texture map. Findings regarding ideal body size were consistent using both identities, where control participants signified a greater discrepancy between their actual and ideal body size, whereas the AN group desired a size similar to their actual BMI (Mölbert et al., 2018). These results suggest the identity of the photographic skin texture may influence perceived body size estimations, where using an individual's texture appeared to result in decreased accuracy, which may reflect self-specific unfavourable body evaluations (Voges et al., 2017).

Although, a methodological concern must be noted as Mölbert et al. (2018) and Piryankova, Stefanucci et al. (2014) presented the women's actual body size in the middle of the stimulus set with an equal number of increased/decreased body sizes on either side, which may have influenced responses if participants were biased towards the centre (see e.g. Figure 1.8). Furthermore, the limited range in body size manipulation may restrict the choices that a participant could potentially make, especially if estimates of ideal body size are to be gained.

Figure 1.8

Examples of 3D avatars used by Mölbert et al. (2018). The top row (a) shows examples of an avatar with the individual's skin texture and average texture. The middle row (b) demonstrates the weight manipulation (+/- 20%) from the participant's actual body weight at 0%.



Hudson et al. (2020) compared perceptual responses using a non-individualised FRS, to three individualised methods: i) 2D presentation of individualised 3D body scans without any texture, ii) 2D presentation of individualised 3D body scans with their own photorealistic skin texture, and iii) VR presentation of individualised 3D body scans with their own photorealistic skin texture. The 2D presentations showed the body stimuli from front-view, whereas the VR presentation used a three-quarter view. All presentations were matched for BMI varying from 18 – 40 in 2 BMI unit increments. There was significantly greater overestimation of perceived body size and increased responses for ideal/realistic body size using the non-individualised FRS. Responses for the individualised methods were similar, with perceived body size accuracy being slightly better for the individualised texture presentations. These findings suggest that there is a benefit of using individualised avatars compared to standardised line-drawing FRS. Using individualised texture may be slightly more beneficial, with no significant benefit of presenting in VR versus 2D. Future work is needed to further investigate the exact amount of stimuli personalization that is necessary, given how time- and resource-intensive the creation of individualised 3D avatars is, using controlled and comparable conditions.

1.6 The Ideal/Most Attractive Female Body Size/Shape

It has been proposed that the ideal female body size/shape is at the low end of the normal BMI range - approximately 18 - 20 BMI units (Hildebrandt & Walker, 2006; Tovée et al., 2002), with a WHR of 0.70 (Henss, 1995; Singh, 1993) and a waist-to-bust ratio (WBR) of 0.70 (Crossley et al., 2012). This suggests a preference for a thin, ‘hourglass’ shaped body (fuller breasts/hips and a smaller waist), which corresponds to the most fertile body size/shape (Jasieńska et al., 2004) and the body size/shape of models (Tovée et al., 1997). Some research suggests this ideal female body size/shape is consistent for both male and female observers (Benninghoven et al., 2007; Crossley et al., 2012; Fingeret et al., 2004; Tovée & Cornelissen, 2001; Tovée et al., 2002), whilst other research suggests that women believe men desire a lower BMI than men actually report (e.g. Bergstrom et al., 2004; Cohn & Adler, 1992; Fallon & Rozin, 1985; Lei & Perrett, 2020).

It has been argued that overall body size/shape (measured by BMI) is a stronger predictor and determinant of body attractiveness than lower body shape (indexed by WHR) (Tovée et al., 2002), as low BMI bodies with higher WHRs are preferred to higher BMI bodies with lower WHRs, although the two are highly correlated. Research using 360-degree videos of models suggests that the strongest predictors of attractiveness are abdominal depth and waist circumference, which suggests that the relationship between BMI and attractiveness can be explained by BMIs association with these other anthropometric measurements (Rilling et al., 2009). Some of these anthropometric markers are not clearly visible when a body stimulus is presented from front-view only, so we should present either a viewpoint where these cues are visible (e.g. three-quarter and/or profile) or multiple viewpoints, for the most precise judgements (Cornelissen et al., 2018).

1.6.1 *'Thin' and 'Fit' Female Body Ideals*

Much research indicates that the 'thin ideal' for women is a prominent and prevalent feature of Western societies, where pressure is placed on women to achieve this ideal (Garner et al., 1980; Spitzer et al., 1999; Sypeck et al., 2004). There is evidence of increasing acceptability of low BMI models over time e.g. the typical body size of female Playboy models decreased from the 1950s to 2000 (Voracek & Fisher, 2002). This ideal may influence body size preferences, for example, cross-cultural research indicates that there are shifts in body size preferences towards a thinner body ideal associated with exposure to Western media (Boothroyd et al., 2016; Thornborrow et al., 2018) or acculturation to a Western environment (Tovée et al., 2006). Another study found that Australian women's body size preferences reflected previous findings of the most attractive body size (approximately 21 - 22 BMI units), whereas this was higher in BMI for Tongan women (24 - 25 BMI units), implying that cultural norms and a

Western thin ideal may influence preferences (Craig et al., 1999). Experimental studies have further corroborated that exposure to thin bodies is associated with a post-exposure preference for thin bodies (e.g. Boothroyd et al., 2012; Bould et al., 2018; Wedell et al., 2005). Some research suggests that there has been an increase in an athletic or ‘fit’ ideal. This body ideal is lean (defined muscularity rather than bulk and size) and comprises a toned upper body and stomach, and a firm/sculpted lower body (Gruber, 2007). Analysis of Sports Illustrated magazine cover pages showed increases in the muscularity of female Olympic athletes from 1956 to 2016 (Dafferner et al., 2019). There were increased ratings of muscularity *and* thinness for Miss USA pageant winners from 1999 to 2013 with ratings of attractiveness remaining stable, and female participants found thin-muscular figures more attractive than just thin figures, suggesting a rise in the prominence and attractiveness of the ‘fit’ ideal for Western women (Bozsik et al., 2018).

Sociocultural explanations of body image and eating disorder psychopathology explain how cultural influences including peers, family, and media link to the transmission and adoption of eating behaviours, body image ideals, and social constructions of what is healthy (Markey, 2004). Socioculturally constructed body ideals may lead to dissatisfaction, as those who internalise the ideal and apply it to themselves (and others) become dissatisfied when they do not meet this ideal, resulting in potentially damaging behaviours to change looks (Clark & Tiggemann, 2008; Slevec & Tiggemann, 2011; Tiggemann, 2011). The thin ideal which is often unattainable may have long-term detrimental effects for those who do not meet this ideal (Couch et al., 2016; Thompson & Stice, 2001). The desire for a thinner body size has been linked to disordered eating (MacNeill & Best, 2015) and internalisation of the thin ideal has been linked to body dissatisfaction, leading to disordered eating symptoms such as dietary restraint, purging and bingeing (Striegel-Moore & Bulik, 2007; Thompson & Stice, 2001). Interactions between thin-ideal internalisation and higher BMI increased the risk of body dissatisfaction and disordered eating psychopathology (Stice & Shaw, 2002). Some research indicates that adolescent females reported a greater drive for thinness, compared to males who reported a higher drive for muscularity (Brunet et al., 2010), however, both ideals were related to greater physique comparison and lower self-esteem, indicating shared outcomes. The ‘fit’ ideal has been referred to as a ‘wolf in sheep’s clothing’, as it is often strived for alongside a thin ideal and does not mitigate the negative effects associated with thin ideal internalisation (e.g. body dissatisfaction, negative affect, disordered eating and dieting) (Uhlmann et al., 2018) and it has been suggested that muscularity concerns and drives in women ought to be considered as potentially contributing to disordered eating psychopathology and negative psychological wellbeing (Cunningham et al., 2019). These findings demonstrate how socio-culturally dominant body ideals can have a significant impact on women’s body image and disordered eating psychopathology and substantiates the need for tools to assess the desire for these ideals.

1.7 Moving Beyond BMI: Measuring Body Size, Shape and Composition

Many of the tools and techniques used in existing body image research tend to focus on a single dimension: body mass index (BMI), which is often used as a proxy for fat mass. An individual’s BMI is easy to calculate using height and weight, is generally a good indicator of health outcomes at the population level, and may be considered the best available tool for monitoring obesity and weight-related risks, but is *not* a direct measurement of fat mass (Green, 2016; Hall & Cole, 2006). Whilst BMI captures overall mass, it does not necessarily capture body shape or weight distribution. A deeper understanding about weight distribution may be understood using circumference measurements (e.g. increased waist circumference may capture abdominal obesity and health risk when BMI does not) (Green, 2016; Visscher et al., 2015) and body shape ratios (e.g. WHR as an indicator of lower body shape) (Wells et al., 2007). However, this still does not provide information about the composition of the weight (whether it is fat or lean mass) (Romero-Corral et al., 2008; Wells, 2019). Lean or ‘muscle’ mass is denser than fat, so two people can have the same BMI but have different body compositions and shapes (Mullie et al., 2008; Yajnik & Yudkin, 2004). There are implications for body image research where a range of samples are involved, such as AN/BN patients, obese people, athletes, and the general population. Using BMI may result in misclassifications for some of these samples, such as being classed as overweight/obese despite having ‘healthy’ levels of fat mass (Wilson et al., 2019). This is common for those with higher levels of lean body mass (Pasco et al., 2014; Prentice & Jebb, 2001), like athletes (Provencher et al., 2018). Alternatively, BMI may underestimate obesity, as an individual may be classed as obese based on their fat mass despite their overall mass (BMI) being below the range considered obese (Frankenfield et al., 2001; Gómez-Ambrosi et al., 2011; Hortobágyi et al., 1994; Okorodudu et al., 2010; Romero-Corral et al., 2008).

There are methodological implications of using body stimuli based on BMI as they may not accurately capture variation in size and shape, resulting in inaccurate perceptions or a failure to capture preferences. Groves et al. (2019) found that men’s self-estimates of perceived body size/shape were influenced by their own body composition and that of the stimuli, resulting in self-estimates that were prone to error. Men with the same BMI but different body composition showed differences in perceived body size estimates which varied by approximately 5 - 7 BMI units and stimuli with low muscle mass resulted in higher self-estimates (approximately 2.5 BMI units). These variations are enough for someone to misclassify their BMI category completely (e.g. estimate their body size as overweight when they are not), suggesting that male stimuli should be appropriately calibrated for body composition to ensure the most accurate estimations. Moreover, a visual adaptation study indicates that there are two dimensions of body shape (fat and muscle) which are perceived independently and encoded by separate neural mechanisms, such that exposure to increases/decreases on one dimension shifts perception on that dimension only and does not generalise to the other dimension (Sturman et al., 2017). This implies that to accurately capture body size/shape estimates, consideration of both fat and muscle mass is necessary.

Some body scales incorporating variations of fat and muscle mass have been created (see e.g., The Body Image Matrix of Thinness and Muscularity - Male Bodies, Arkenau et al., 2020; The Somatomorphic Matrix, Gruber et al., 1999; The Bodybuilder Image Grid, Hildebrandt et al., 2004). The majority of these scales were created using line-drawings based on artistic impressions of human models varying in fat and muscle (e.g., The Somatomorphic Matrix, Gruber et al., 1999 and the Bodybuilder Image Grid, Hildebrandt et al., 2004). These images are therefore subject to the same limitations as traditional FRS discussed earlier in terms of ecological validity and realism. Additionally, The Somatomorphic Matrix presents only the front-view of the body which arguably misses information necessary for making accurate judgements (Cornelissen et al., 2018). Kagawa et al. (2006) suggested that 3D body shapes should be presented from multiple viewpoints rather than front-view only to aid accurate judgements. Moreover, whilst the Bodybuilder Image Grid did demonstrate adequate test-retest reliability and convergent validity (i.e. self-estimates using the scale significantly correlated with measures of activity, BMI, and some psychometric measures) (Hildebrandt et al., 2004), the Somatomorphic Matrix was not found to demonstrate sound test-retest reliability in men or women, so may not be considered a reliable tool for use in future body image research (Cafri et al., 2004; Kagawa, et al., 2006). The findings from empirical studies using the Somatomorphic Matrix are inconsistent (Cafri & Thompson, 2004) and some studies have questioned whether the stimuli accurately capture body composition (Kagawa et al., 2006).

Recent adaptions have used high-quality, photorealistic, standardised CG body stimuli. For example, the Visual Body Scale for Men (Talbot et al., 2019) was developed by replicating the hand-drawn figures from Cafri and Thompson's (2004) Modified Somatomorphic Matrix. This new scale consists of two one-dimensional scales separately capturing fat and muscle. Despite showing good psychometric properties (an improvement on the previous line-drawing version), the stimuli were replicated from drawings without any statistical calibration, which means that the precision of the stimuli should be questioned and that a direct comparison to the person's actual body composition is unlikely to be accurate. Furthermore, using one-dimensional scales fails to capture the interaction between fat and muscle, limiting the ability to accurately capture a person's perceived/ideal body composition (a specific combination of fat and muscle). The 'New Somatomorphic Matrix - Male' (Talbot et al., 2018) was similarly created by emulating the Modified Somatomorphic Matrix with CGI, utilising combinations of fat and muscle mass rather than one-dimensional scales. Again, this scale demonstrated sound psychometric properties and better test-retest reliability than the Somatomorphic Matrix, but similar concerns regarding stimuli precision and mapping to the person's actual body composition remain. Moreover, the validation study was completed online using self-reported BMI, which limits the examination of how the scale relates to the individual's actual body composition (Talbot et al., 2018). Arkenau et al. (2020) developed the 'The Body Image Matrix of Thinness and Muscularity', consisting of 64 CG male bodies varying in combinations of fat and muscle. This was shown to demonstrate sound psychometric properties in men, however, the stimuli were not based on actual anthropometric data and do not allow a direct comparison to the participants' actual body composition (Arkenau et al., 2020). These CGI body composition scales were created and validated for men, which ignores muscularity concerns and ideals which may be pertinent for women (Garner, 1997; Gruber, 2007). To date, a well-validated and appropriately calibrated CGI body composition scale based on anthropometric data (with direct mappings to actual body composition) has not been created for the assessment of body image in women.

Research suggests that fat and muscle has differential effects for female ideals/attractiveness. Brierley et al. (2016), used photographs and unstandardized regression residuals to manipulate the fat and muscle mass of the person in the photograph. Photographs were taken from a sample of Caucasian adults aged 18 - 30 (128 females), each associated with the individual's body composition (body fat and muscle mass). All images were landmarked. Linear regressions were used to predict fat and muscle separately (controlling for the other body composition variable and height) and the unstandardized residuals were saved for each regression. Composites of high and low muscle/fat images were then created using the photographs of the 10 individuals with highest and lowest residual scores from each regression, to denote the endpoints of the fat and muscle manipulations. These composite endpoints were used to linearly morph individual photographs to simulate variation in fat and muscle in 13 equal steps, resulting in a total of 169 images varying in fat and muscle (see Figure 1.9 for an example). This method is based on anthropometric data, which means that is it more ecologically valid and accurate manipulation of body shape than other photo distortion techniques e.g. width distortion. Using these stimuli, they found that perceived attractiveness was driven by a preference for lower fat but not lower muscle mass, compared to that considered a healthy body. The body fat percentage of the most attractive female body was lower (16.31%) than for healthy (19.16%), which were both lower than that considered healthy according to guidelines (21.00%).

Figure 1.9

Example of an individual stimulus featuring the high, low and mid-points of fat and muscle manipulations. Taken from Brierley et al. (2016).

Similar findings were obtained from Lei and Perrett (2020), using 3D CGI models simulated to vary in BMI and body fat percentage, where body fat percentage is inversely related to muscle mass so that a lower percentage is associated with increased visibility of muscularity, as no simulation of muscle mass was available. The findings indicated that women's ideal body composition (21 BMI units and 24% body fat) was significantly lower in BMI but higher in muscularity than that considered the healthiest (23 BMI units and 25% body fat). Women thought that men would desire a lower BMI than they actually reported as the most attractive and this was exaggerated for short-term relationships, suggesting that women misperceive men's preferences for body size. However, perceptions of body fat percentage were accurate, suggesting accurate perception of men's muscularity preferences. It was also found that women's perceptual body dissatisfaction was predicted by perceptions of what the opposite-sex would find most attractive in terms of BMI, for example, the more women perceived men as desiring lower BMI females, the higher their levels of body dissatisfaction. It must be acknowledged that the CGI models were generated from a mobile phone app, where information regarding stimulus development and validation is unknown. The BMI preferences from this study were slightly higher compared to previous findings, so stimulus accuracy is unclear and questionable (Lei & Perrett, 2020). Nevertheless, these findings indicate that using stimuli varying in body composition provides useful information regarding female attractiveness/ideals/health from both same- and opposite-sex observers, supporting the need for an appropriately calibrated body composition scale for women.

1.7.1 *Factors Influencing Body Size/Shape/Composition*

Three key factors that influence body size/shape, composition, and weight distribution are sex, ethnicity, and age. Sexual dimorphism in human body composition is apparent throughout the lifespan, where males typically have greater lean mass and from childhood women typically have more fat mass (Gallagher et al., 1996; Wells, 2007). Even at the same BMI, women typically have higher body fat and less lean mass than men (Jackson et al., 2009). Wells et al. (2007) found that height was the strongest predictor of weight for both sexes, however, the second strongest predictors after adjusting for height differed between sexes (waist and chest circumferences for men and hip and bust circumferences for women). Moreover, there are variations in body size/shape/composition across the lifespan. Typically, BMI increases until around 55 years of age when it then decreases, with women displaying a greater magnitude of weight change than men (Williamson, 1993). Skeletal muscle mass appears to stay relatively stable in adults until around 50 years of age when it starts to decrease, particularly in the lower body (Janssen et al., 2000). Age is strongly associated with shape in women, with increased upper body circumferences (particularly waist but also bust) and decreased thigh circumference, suggesting that weight tends to move upwards and more centrally in older women (Wells et al., 2007), compared to a more hourglass shape for younger women (Wells et al., 2008).

Furthermore, ethnic differences in the distribution and composition of body weight are apparent. One study found differences in fat deposition between South Asian and Caucasian adults, where South Asian adults had higher abdominal/truncal obesity and less skeletal muscle mass (Misra & Khurana, 2011). Significant differences in waist and hip circumferences were found between UK and Thai adults (and bust in females), after adjusting for height and BMI (Wells et al., 2012). Rush et al. (1997) found that Polynesian adults had significantly higher BMI at a comparable body fat percentage to New Zealand European adults. As fat increased the European adults tended to store fat centrally, whereas distribution did not change for Polynesians. The Polynesian and New Zealand Europeans differed in body composition, such that predicting body fat from skinfold and girth measurements was ethnicity dependant. Similarly, significant differences between the body composition (Fat-Free Mass [FFM] and body fat percentage) and shape (waist circumference and WHR) of Tongan and Caucasian Australian women have been identified (Craig et al., 2001). Subsequently, the use of European BMI classifications is not applicable among some ethnic groups because of differences in weight characteristics to adults of

European descent (Craig et al., 2001; Wang et al., 1994). These factors should be considered in the development and evaluation of body stimuli.

1.8 Thesis Aims and Rationale

The literature presented in this chapter provided an overview of body image and its two components (perceptual and attitudinal), with the focus of this thesis being on the assessment of the perceptual component. The implications of body image disturbances across the BMI spectrum were discussed, such as mental/physical health outcomes and impacts for eating disorder recovery and treatment. Several factors which influence perceptions of body size/shape were identified, such as an individual's psychopathology, actual body size/shape, socio-cultural influences, and potential methodological issues associated with existing techniques. The need to develop tools and stimuli to accurately assess perceptual body image and interventions to specifically target body image disturbances were highlighted.

Therefore, the main aim of this thesis was to develop measures/techniques used to investigate perceptions of female body size/shape, using CG and 3D scanning technologies. Throughout, the factors associated with perceptions of female body size/shape were considered and the psychometric properties (reliability and validity) of the novel stimuli/measures were assessed. First, an existing body size perception intervention was replicated and extended, and a novel approach to assessing and analysing perceptual body image was employed (Chapter 3). Second, CG body stimuli calibrated for BMI were created (Chapter 2) and used to develop data-driven FRS to address unanswered questions and methodological concerns with existing scales (Chapter 4). Next, 3D scanning technology was used to develop anthropometrically-calibrated body stimuli, generated by collating a large database of female body scans each associated with anthropometric measurements (Chapter 2). The 3D body shapes were first used to investigate perceptions of BMI and attitudes towards weight loss across the BMI spectrum (Chapter 5). Lastly, moving beyond BMI, a novel statistically-calibrated body composition (fat and muscle) scale was created using the 3D body shapes. This was used to explore perceptions of female body composition and to investigate the scales psychometric properties (Chapter 6).

Chapter 2: General Methodology

A series of measures have been taken throughout the experimental studies. To avoid repetition, commonly used measures have been described below.

2.1 Body Measurements

The participant's actual body measurements were taken in each laboratory study to account for body size/shape as a factor which may be related to performance and findings.

2.1.1 *Body Mass Index (BMI)*

The following formula was used to calculate BMI: weight (kg) / height (m)^2. Weight was taken using a set of calibrated scales. Standing height was taken to the nearest mm using a seca 213 stadiometer. All participants were instructed to remove shoes and stand up tall, facing straight ahead. The BMI categories used in this thesis are defined by the World Health Organisation (WHO), Europe (WHO, 2019). There are four main categories (underweight, normal weight, overweight, and obese) and three sub-categories within the obese range (see Table 2.1).

Table 2.1

The Body Mass Index categories as defined by World Health Organisation, Europe.

Underweight	Normal weight	Overweight	Obese		
			Obesity Class I	Obesity Class II	Obesity Class III
<=18.49	18.50 – 24.99	25.00 – 29.99	30.00 – 34.99	35.00 – 39.99	>= 40.00

2.1.2 *Circumference Measurements*

Circumference measurements were taken in cm using a tape measure. The participants took the measurements themselves, with help from the researcher for the relaxed arm girth. Participants were instructed on where to take the measurements from and readings were taken by the researcher. Chest/bust measurements were taken from around the largest part of the chest. Waist measurements were taken from just above the belly button. Gluteal (low hip) measurements were taken from the largest part of the bottom. Lastly, relaxed arm girth measurements were taken from the right arm, at the mid-point between the elbow and the shoulder.

2.1.3 *Body Composition using Bioelectrical Impedance Analysis (BIA)*

Full-body and regional body composition was measured using a Tanita Multi-Frequency Segmental Body Composition Analyser (model MC-780MA). This device has eight electrodes (four on the handgrips and four on the base of the scale where the feet are placed). A safe, low-level electrical current is sent through the participant's body to determine estimates of body composition. The full-body values outputted from this device are, body fat (kg and percentage), muscle mass (kg), skeletal muscle mass (kg and percentage), bone mass (kg), water (kg and percentage, with extracellular and intracellular mass in kg), basal metabolic rate (kcals), visceral fat level (scale of 0 - 59), weight (kg), fat-free mass (kg) and BMI (calculated by providing height in cm). Regional values are divided into five regions: trunk, left leg, right leg, left arm and right arm, with values for fat mass (kg and percentage), fat-free mass (kg) and muscle mass (kg) outputted for each area.

Bioelectrical impedance analysis scales are relatively inexpensive, easy and quick to use, and are less prone to technical error than other methods, which is useful in large-scale studies (Lee & Gallagher, 2008). Body composition estimates are made by measuring impedance (opposition to the flow of electrical current). Based on the two-component model of body composition (fat and fat-free mass), an estimate of total body water is acquired first, followed by fat-free mass on the premise that 73% of the body's fat-free mass is water (Lee & Gallagher, 2008). Some research suggests there is good agreement between Dual-energy X-ray absorptiometry and BIA when measuring full-body lean mass, fat mass and body fat percentage in both men and women, with limits of agreement widening as fat increases (Ling et al., 2011). The reliability coefficients of BIA have been shown to vary between .93 and .96, with body fat percentage accuracy being between 3 and 5% (Gallagher & Javed, 2009) or 5 and 6% in other studies (Jackson et al., 1988).

Here, test-retest reliability and validity of body composition measures taken using the Tanita BIA scale are reported, using a subset of the sample used to generate a 3D body scan and composition database (detailed in Section 2.4 of this chapter).

Validation of Body Fat Estimates. To assess the validity of the body fat measurements taken from BIA, skinfold measurements were taken by a Level 2 International Society for the Advancement of Kinanthropometry (ISAK) practitioner from 22 Caucasian women (M_{age} = 22.46, *SD* = 6.66; M_{BMI} = 21.75, *SD* = 2.49), following the standard ISAK procedure (Stewart et al., 2012). Skinfold measurements were taken from eight sites (tricep, bicep, subscapular, iliac crest, supraspinale, abdominal, medial calf, and front thigh) using skinfold callipers. For analysis, the average of two measurements was used, unless the values differed by 5% or more, then a third measurement was taken and the median value was used. A sum of four skinfolds was calculated by summing skinfold values from the abdominal, tricep, front thigh, and iliac crest. An overall body fat percentage was estimated using the Jackson and Pollock (1985) equation which includes the sum of four skinfolds and age:

$$(0.29669 * \text{sum of skinfolds}) - (0.00043 * \text{square of the sum of skinfolds}) + (0.02963 * \text{age}) + 1.4072$$

An estimate of fat mass (kg) was then calculated based on participants' total body weight and estimated body fat percentage using the Jackson and Pollock (1985) equation.

Pearson's correlations were used to look at the relationship between fat estimates (percentage and mass) taken from the calliper method and BIA. There were significant, positive correlations between the fat values derived from each method (n = 22, see Table 2.2).

Table 2.2

Pearson's correlations depicting the relationship between Bioelectrical Impedance Analysis (BIA) and calliper estimates of fat mass and percentage.

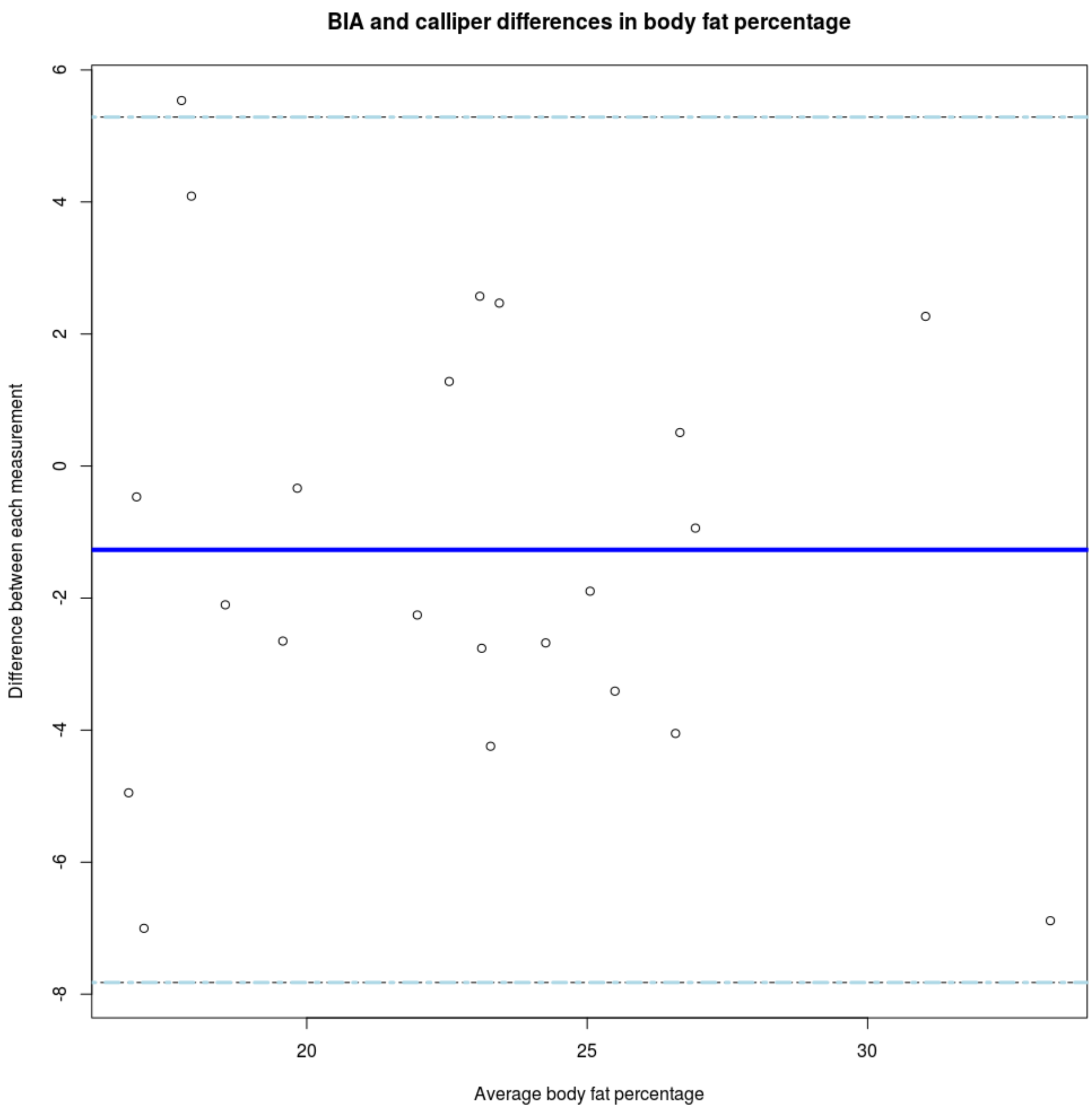
	Calliper Fat Percentage	Calliper Fat Mass
BIA Fat Percentage	.76 ***	.77 ***
BIA Fat Mass	.80 ***	.89 ***

*** $p < .001$, ** $p < .005$, * $p < .05$

Body fat percentage from the calliper methodology (M = 22.15, SD = 4.59) was slightly lower than the BIA value (M = 23.42, SD = 5.03). On average, these values did not significantly differ ($t(41.65) = -0.87$, p = .387). The mean difference between the two measurements was -1.27% which was not statistically different from 0 ($t(21) = -1.78$, p = .090). The absolute agreement between the two measures was significant (Intraclass Correlation Coefficient = .85, $F(21, 19.40) = 7.29$, p = < .001, 95% CI [0.64 – 0.94]), suggesting good agreement between the estimates (see Figure 2.1).

Figure 2.1

A Bland-Altman plot showing the agreement between BIA and calliper estimates of body fat percentage. The mean difference is -1.27%, represented by the solid blue line. The upper (5.29%) and lower (-7.82%) 95% limits of agreement are denoted by the dash-dotted light-blue lines.



Intra-Individual Reliability. To assess the reliability of body composition measurements from the BIA, repeat measurements were taken from nine women (M_{age} = 21.89, *SD* = 3.59; M_{BMI} = 21.88, *SD* = 2.09), approximately 20 - 30 minutes apart. Four body composition variables were considered: fat mass, body fat percentage, muscle mass, and fat-free mass. Pearson’s correlations indicated significant, positive correlations between body composition values for all four variables between time one and two (r’s > .99, p’s < .001). Comparisons between the values at both time-points demonstrated excellent agreement, the Intraclass Correlation Coefficient (ICC) for each variable was > .99 (p < .001).

2.2 Psychometrics

A variety of validated self-report measures were used to assess an individual’s psychological, cognitive-affective state. These included questionnaires related to eating disorder psychopathology, body, shape and weight concerns, depressive symptoms, self-esteem, and the internalisation of body ideals. These questionnaires have been used throughout the studies in this thesis. All of these measures can be found in Appendix A.

2.2.1 *Body Shape Questionnaire 16-B (BSQ 16-B; Evans & Dolan, 1993)*

The 16-item BSQ developed by Evans and Dolan (1993) is a shortened version of the full 34-item version (Cooper et al., 1987). There are two versions of the 16-item BSQ, with 16-B being used throughout this thesis. The BSQ measures body, shape and weight concerns on a scale of 1 (never) to 6 (very often) based on the last 28 days, e.g., “Has seeing your reflection (e.g. in a mirror or shop window) made you feel bad about your shape?” One item contains sex-specific wording ("Have you noticed the shape of other women and felt that your shape compared unfavourably?") which is changed to ‘men’ when used with a male sample. The BSQ has been shown to have good test-retest reliability, concurrent validity, and criterion validity (Rosen et al., 1996). The 16-item versions have also been shown to have good internal reliability and concurrent validity (Evans & Dolan, 1993). The BSQ was scored by summing the answers. A higher score indicates higher body, shape and size concerns.

Using total scores, people can be categorised into different levels of body, shape and weight concern (Taylor, 1987). Scores below 38 indicate ‘no concern with shape’, 38 - 51 indicate ‘mild concern with shape’, 52 - 66 indicate ‘moderate concern with shape’ and scores over 66 indicate ‘marked concern with shape’.

2.2.2 *The Eating Disorder Examination Questionnaire 6.0 (EDE-Q; Fairburn & Beglin, 1994, 2008)*

The EDE-Q measures disordered eating psychopathology using four subscales: dietary restraint, eating concerns, weight concerns, and shape concerns. This questionnaire was adapted from the Eating Disorder Examination, an interview assessing the range and severity of eating disorder features. The questionnaire consists of 28 questions based on a time scale of the past four weeks (28 days). Some questions are assessed using a 7-point scale from 0 - 6 e.g. “Have you had a definite fear that you might gain weight?” 0 (No days) – 6 (Every day); “Has your weight influenced how you think about (judge) yourself as a person?” 0 (Not at all) – 6 (Markedly). Some questions are based on frequency, with an open-ended response e.g. “Over the past 28 days, how many *times* have you eaten what other people would regard as an *unusually large amount of food* (given the circumstances)?”. This questionnaire has been shown to have good internal consistency (Aardoom et al., 2012), test-retest reliability (Luce & Crowther, 1999), concurrent validity (Mond et al., 2004) and criterion validity (Aardoom et al., 2012; Mond et al., 2004; Mond et al., 2008). This has been supported through a systematic review looking at the psychometric properties of the EDE-Q in several studies (Berg et al., 2012).

Scores for each of the four subscales were calculated by summing answers on the 0 - 6 scale and dividing by the number of items in the subscale to create a mean score. The mean scores were then summed and divided by the number of subscales (4) to create an overall, global score.

2.2.3 *Beck Depression Inventory (BDI; Beck et al., 1961)*

The BDI is a 21-item self-report measure of depression on a scale of 0 - 3 e.g. Mood: 0 (I do not feel sad) to 3 (I am so sad or unhappy that I can't stand it). It is a commonly used measure which assesses a variety of depressive symptoms e.g. fatigue, irritability, sleep and self-hate. This measure has high internal consistency (Beck et al., 1988), concurrent validity (Beck & Steer, 1984; Beck et al., 1988; Storch et al., 2004), acceptable test-retest reliability (Wiebe & Penley, 2005), and convergent validity (Richter et al., 1998). These psychometric properties have been supported through a systematic review of the psychometric properties of the BDI-II (Wang & Gorenstein, 2013). Scores were calculated by summing participants' responses on the 0-3 scale. A higher score indicates higher depressive symptoms.

2.2.4 *Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965).*

The RSES is a 10-item measure of self-esteem on a scale of 1 (strongly agree) to 4 (strongly disagree) e.g. "I feel that I'm a person of worth". Half of the items are positively worded and half are negatively worded. This measure is a commonly used assessment of global self-esteem. It has been shown to have a one-factor structure, showing good internal consistency and criterion validity (Beeber et al., 2007). Internal consistency in a sample of UK participants was high ($\alpha = .90$; Schmitt & Allik, 2005). Self-esteem is a significant predictor of disordered eating psychopathology; correlating highly with disordered eating, a desire for thinness, body dissatisfaction and body concerns, and the RSES demonstrated good construct validity (Greenberger et al., 2003; Griffiths et al., 1999). Overall, the RSES has demonstrated good internal consistency, convergent and discriminant validity (Sinclair et al., 2010). Scores were calculated by summing answers, with the negatively worded items reverse scored. A higher score indicates higher self-esteem.

2.2.5 *Sociocultural Attitudes Towards Appearance Questionnaire 4 (SATAQ-4) – Thin/Low Body Fat and Muscular/Athletic Internalization Subscales (Thompson et al., 2011).*

These SATAQ-4 subscales measure the internalisation of societal appearance ideals.

Thin/Low Body Fat Internalisation Subscale. In this subscale, 5-items assess a person's desire for a thin/low-fat body (e.g. "I think a lot about having very little body fat"), on a 5-point scale from 1 (definitely disagree) to 5 (definitely agree). This subscale assesses a person's internalisation of sociocultural ideas and attitudes regarding 'thinness', such that thinness becomes a socially-accepted guiding value in one's life (Pedersen et al., 2018). Striving for this body type may be detrimental because it can lead to the pursuit of a body type that is unattainable by a lot of people (Thompson & Stice, 2001).

Muscular/Athletic Internalisation Subscale. In this subscale, there are 5-items which assess a person's desire for an athletic body type (e.g. "It is important for me to look athletic"), on a 5-point scale from 1 (definitely disagree) to 5 (definitely agree). An athletic body type is not too muscular but is lean with defined muscularity - a 'toned' figure, and may be increasing in prominence as an appearance ideal that women strive for (Gruber, 2007). Internalisation of this ideal has been found to influence disordered eating – bulimic symptomology and restrained eating, and compulsive exercise behaviours, but not body dissatisfaction in a non-clinical female sample (Bell et al., 2016).

The internal consistency of these subscales is good (α >= .82) in samples of US, Italian, Australian and English women, and the thin-ideal subscale significantly correlated with measures of eating disorder symptomology, body satisfaction and self-esteem, suggesting good convergent validity (Schaefer et al., 2015; Thompson et al., 2011). The thin-ideal subscale has also been shown to demonstrate good discriminant validity for clinically-significant eating disorder symptomology (Schaefer et al., 2019). The authors found a score of 3.78 on the thin-ideal subscale was the optimal cut off, which provided an optimal balance of specificity and sensitivity (specificity = .64; sensitivity = .81).

The subscales were scored independently. Scores were calculated by summing answers, then dividing the total score by the number of items in each subscale (5). A higher score indicates higher levels of appearance-ideal internalisation relating to either a thin or athletic body type.

2.3 Female Computer-Generated Body Stimuli Calibrated for BMI

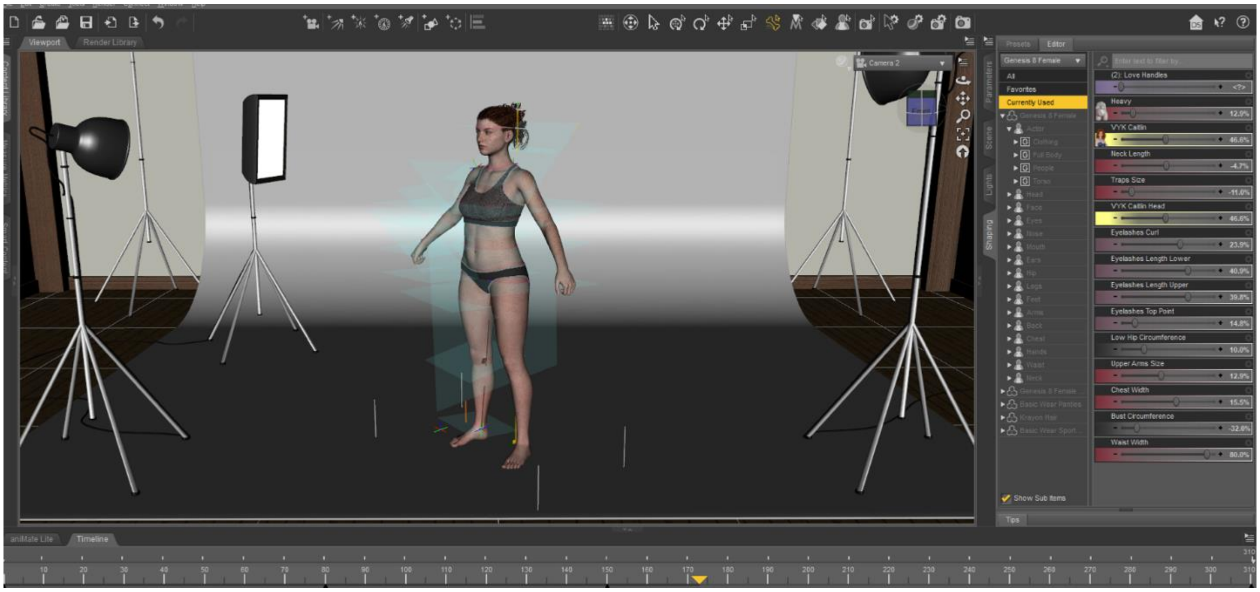
In Section 1.5.2, Chapter 1, the benefits and use of Computer-Generated (CG) body stimuli in experimental research were discussed (e.g. Cornelissen et al., 2017; Gledhill et al., 2017; Moussally, Rochat et al., 2017; Thornborrow et al., 2018). Standardised CG images varying in BMI have been demonstrated to plausibly and accurately capture body size changes (Cornelissen et al., 2015; Moussally Grynberg, et al., 2017). Here, a set of female stimuli has been created and used in Chapter 4. The following section describes the creation and calibration of the stimulus set.

The stimuli were created using Daz Studio (v. 4.10; Daz3D.com), which is a 3D modelling program. This program allows the creation of realistic 3D models that can be altered using a variety of different morphs to create a range of different body shapes and sizes. There are a variety of different models, characters, skins, and accessories which can be used to customize the 3D models. Manipulating the models using morphs means that the photographic identity of the model can remain the same while body size and shape is altered. There are a large number of morphs available, including full-body (e.g. weight, body size, thin, heavy), and body-part specific (e.g. upper arm size, thigh size, waist width, glutes size). The morphs are altered using sliders which allow the percentage of the morph to be changed in increments of 0.01%.

To create the stimulus, firstly, a base body was created to represent a life-like female body using a Genesis 8 model with the skin texture of 'VYK Caitlin' applied using the Iray render engine. This character skin was chosen as it represents a Caucasian female with photo-realistic skin texture. Based on patient and public involvement feedback, which I conducted with current/ex-service users and clinicians at the local eating disorder service (Lincolnshire Partnership NHS Trust), it was important to have a figure that did not look too airbrushed or 'perfect', so a character with skin blemishes was chosen. The base body was set to a three-quarter viewpoint (45-degree angle; see Figure 2.2). This angle was chosen as previous research has shown that body size discrimination accuracy is best at this viewpoint as it allows the observer to capture a range of cues about body size e.g. stomach depth (Cornelissen et al., 2018).

Figure 2.2

Daz Studio interface with 'VYK Caitlin' base body at a 45-degree angle position in the Z Photo Studio environment, and examples of the morphs on the right-hand side of the screen.



Calibration of the base body used for the stimulus set followed a methodology previously used by Cornelissen (2016). The base body was calibrated for BMI and shape to simulate realistic changes in body size across the BMI spectrum. To validate the plausibility of this weight and shape change, Cornelissen (2016) compared the calibrated stimuli to a statistical model of 3D scanned bodies and photographs of female participants at various BMIs. The calibration was based on Health Survey for England 2008 data (HSE; HSE, 2008) to represent the average shape of a Caucasian woman in the UK. As such, the base body was set to a height of 165.20cm, waist circumference of 69.53cm, hip circumference of 92.07cm, and a waist-to-hip ratio of 0.76. This is a BMI of approximately 19.79 (assuming an age of 29 years old). These specific measurements and age were chosen because they represent the average statistics of Caucasian women, 18 - 20 BMI units, aged 18 - 45 years in the UK (HSE, 2008). A base body of this BMI was chosen as it is the default size of the Daz starter model, and it allowed for the full range of BMI units (14.25 - 44.00) to be captured using the morphs.

The BMI of the body was estimated using the BMI calibration equation shown below, which explained 90.24% of the variance in BMI. See Cornelissen (2016) for more information on the development of this equation:

$$yi = \beta0 + \beta1.x1 + \beta2.x2 + \beta3.x3 + \beta4.x4 + \beta5.x4^2 + \epsilon i$$

yi = BMI, x1 = hip circumference, $x2$= waist circumference, $x3$ = height, $x4$ = age, β0 = 9.676, β1 = 0.308, β2 = 0.150, β3 = -0.179, β4 = 0.0554, β5 = - 0.000762 and ϵi = residual error.

To create the desired range of stimuli, the base body was manipulated using three full-body (emaciated, thin, and heavy), and two body-part specific sliders (upper arm size and breast size). A total of 310 frames were categorized into four keyframes, whereby body size and shape were varied using different slider manipulations (Table 2.3). The manipulation of body size was similar to that followed by Cornelissen (2016), with the addition of an increased upper arm size and a lower breast size. The decision to change arm and breast size was based on informal, qualitative feedback from colleagues and patient and public involvement discussions. Data from HSE (2008) does not include anthropometric statistics related to bust or arm circumferences. The breast size was reduced only for keyframe 1 as feedback from clinicians indicated that the breast size remained unnaturally larAge at the lower end of the BMI spectrum in this model. The upper arm size was increased only for keyframe 4 to create a more natural-looking arm size at the higher end of the BMI spectrum, as feedback on previous images was that weight increases were mainly focused around the stomach and the hips, with little change in the size of the arms.

Table 2.3

The position of the Daz morph sliders for each keyframe.

Key frame	Frame	Slider Position				
1	0	emaciated = 1	thin = 1	heavy = 0	upper arm size = 0	breast size = -.76
2	80	emaciated = 0	thin = 1	heavy = 0	upper arm size = 0	breast size = -.32
3	150	emaciated = 0	thin = 0	heavy = 0	upper arm size = 0	breast size = -.32
4	310	emaciated = 0	thin = 0	heavy = 1	upper arm size = 1	breast size = -.32

Note. As mentioned earlier, the morph sliders vary by percentage. Here the numbers are presented in decimal form, where 1 indicates the maximum/highest on the slider and 0 is the minimum/lowest on the slider for emaciated, thin, and heavy, whereas, -0.50 and -1 are the minimum/lowest for upper arm size and breast size, respectively.

As outlined by Cornelissen (2016) the model was measured at every 10th frame to get measurements of waist and hip circumference. The BMI was then calculated using the calibration equation specified above. The BMI values for each of the 310 frames were then estimated by interpolating the values between the measurements taken from every 10th frame (assuming a linear increase in waist and hip measurements). This was calculated in R Studio using the 'na.approx' function from the 'zoo' package (R Studio Desktop 1.1.463; Zeileis & Grothendieck, 2005).

Before rendering the final images, it was important to determine whether the body size changes looked realistic and plausible. Examples of the stimuli in each BMI category were shown to colleagues to get some informal qualitative feedback regarding the plausibility and realism of the bodies across the BMI spectrum. See Figure 2.3 for an example of one image from each BMI category. Stimuli were rendered in high-definition by selecting frames which most closely corresponded to increments of 0.25 BMI units apart. The selected frames were rendered at 1120 x

880 pixels at 32-bit depth, resulting in a stimulus set of 120 images ranging from 14.25 to 44.00 BMI units (see Appendix B for a full overview of the rendered frames).

Figure 2.3

An example of a rendered CG body in each WHO BMI category from underweight (left) to obese class III (right).

2.4 The Development of a 3D Scan and Body Composition Database.

In Section 1.5.2 of Chapter 1, the applications of 3D scanning technology in shape variation visualization and for stimulus creation were discussed. One statistical model of BMI has been used in perceptual body image research to generate 3D avatars (e.g. Mölbert et al., 2018; Piryankova, Stefanucci et al., 2014; Thaler, Geuss et al., 2018; Thaler, Piryankova et al., 2018), but there is still a need for a statistical model capturing a wider variation in body size/shape and one which allows manipulations of body composition rather than just weight. Here, a database of 3D body scans and accompanying anthropometric and body composition measurements were collected from a sample of UK women, to subsequently be used to generate calibrated stimulus for body size/shape perception research (Chapters 5 and 6). Below, the development of this database is described and summary statistics are reported and discussed.

Ethical approval was gained from the School of Psychology Research and Ethics Committee at the University of Lincoln (Project code: PSY1718350).

2.4.1 *Participants*

A total of 310 females aged between 18 and 71 years old (*M* = 34.72, *SD* = 12.94) with BMIs ranging from 16.57 - 38.05 (*M* = 24.08, *SD* = 4.21) were recruited. The sample was predominantly Caucasian (92%). Participants were recruited from the University of Lincoln and surrounding areas using opportunity sampling including social media advertisements, word-of-mouth and through local gyms. No financial compensation was given but undergraduate psychology students could participate in return for course credits.

2.4.2 *Apparatus*

3dMD Body Scanner. A “temporal-3D” surface imaging software system by 3dMD was used to capture high-resolution, colour 3D body scans (3dMD, 2020). This system contains nine modular camera units to capture 360-degree full-body scans. Each unit contains four cameras comprising three different types of cameras: monochromatic (two per unit), speckle, and colour (one of each per unit). The system outputs a continuous 3D polygon surface mesh with a mapped surface texture (i.e. the individual’s photographic identity). The system has a linear accuracy range of 0.7mm or better, resulting in high-precision surface images (3dMD, 2020). Each scan takes a maximum of 20 seconds, recording at seven frames per second.

Body Measurements. Body measurements were taken from all participants using the Tanita BIA scale and height was taken to the nearest mm using a stadiometer. See Section 2.1, for more details.

2.4.3 *Procedure*

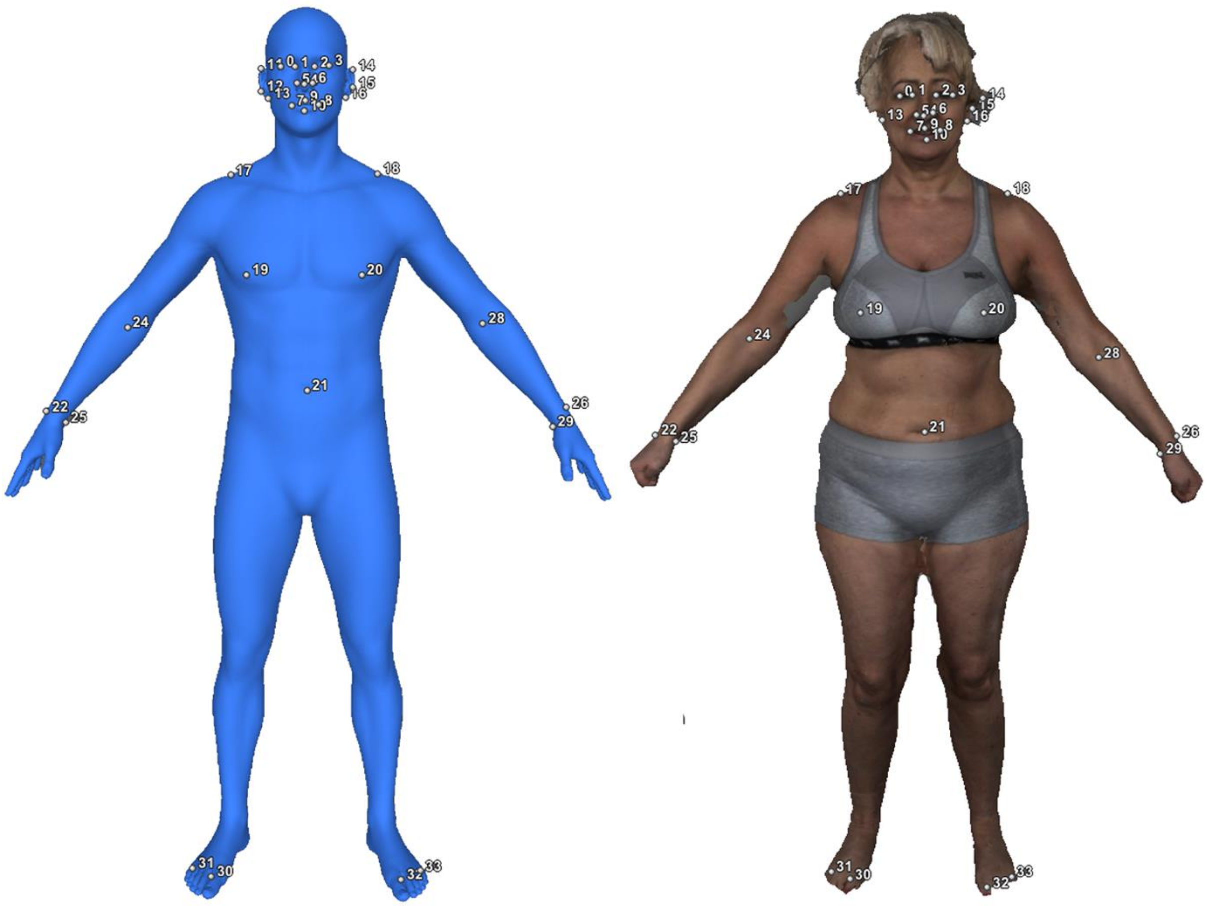
Participants were first scanned using the 3dMD full-body scanner. This involved the participant standing on a platform in the centre of the scanner for 20 seconds while the cameras took a video. The participants were asked to stand with their feet shoulder-width apart and to raise their arms to shoulder level with their hands in a fist, to capture a range of arm positions. Participants were provided with grey underwear (in a size chosen at their discretion) to ensure that body shape was not disguised by clothing and to prevent compromising scanning accuracy which may be affected by dark reflective clothing. Lastly, body measurements were taken and demographic information (age and ethnicity) were recorded.

2.4.4 *Scan Processing and Registration*

The scan meshes were processed and registered using Russian 3D Scanner Wrap software (Version 3.3.17) (Russian 3D Scanner, 2018). This software was used to repair missing segments of the meshes, remove invalid polygons, and fix non-manifold topology. A frame from the individual's scan where an 'A pose' was adopted was selected by the researcher. Using the wrapping node, a common topology was applied to all scans by matching each mesh to a standardised base mesh, using a set of 36 pre-selected landmark points, manually selected by the researcher (see Figure 2.4). The wrapping process uses non-rigid fitting to deform the standardised base to each scan, to ensure that individual variation is maintained whilst creating correspondences between each scan, such that the vertices on each scan represent the same location. Each final mesh consisted of 79, 522 vertices and was used for further statistical analyses to allow comparisons to be made.

Figure 2.4

Standardised template base mesh (left) and an example of a landmarked 3D scan (prior to processing) (right). Both are presented at front-view here so the remaining two landmarks (currently not visible) are located on the backs of each ankle.



2.4.5 *Summary Statistics of the Female Body Composition Database*

Body Measurements and Participant Characteristics. The final sample used for stimuli creation and in statistical analyses for this thesis was limited to Caucasian females aged 18 - 45 years old, to minimise body composition variability from ethnicity and age (Gallagher et al., 1996). This resulted in a final sample of 221 women. Table 2.4 presents a summary of the samples body measurements and participant characteristics and Table 2.5 presents the relationship between these variables, determined using Pearson’s correlations. A range of body composition variables were collected, the main ones of interest for this database were BMI, fat mass and skeletal muscle mass (SMM). We focused on SMM as skeletal muscles are those which are under voluntary control and are used to assist movement (e.g. the biceps), and does not include the smooth muscles (e.g. cardiac and digestive) (Dave & Varacallo, 2019). The muscle mass value from the Tanita BIA includes SMM, smooth muscles and the water contained in these muscles, which do not necessarily reflect outer body size/shape, and provides a very similar output to overall fat-free mass (shown in Tables 2.4 and 2.5).

Table 2.4

Summary of body measurements and participant characteristics.

Measurement	*M*	*SD*	Min.	Max.
Age	29.14	8.18	18.00	45.00
Height (cm)	164.63	6.29	141.50	181.00
Weight (kg)	64.58	11.92	37.30	119.20
BMI	23.82	4.19	16.69	38.05
Body fat (%)	26.29	7.05	7.90	44.40
Body fat (kg)	17.65	7.92	4.20	52.90
Fat-free mass	46.92	5.30	31.90	66.30
Muscle mass (kg)	44.54	5.04	30.30	63.00
SMM (kg)	26.34	2.79	18.90	35.10
SMM (%)	41.55	5.19	29.00	57.90

Table 2.5

The relationship between anthropometric measurements, determined using Pearson's correlations.

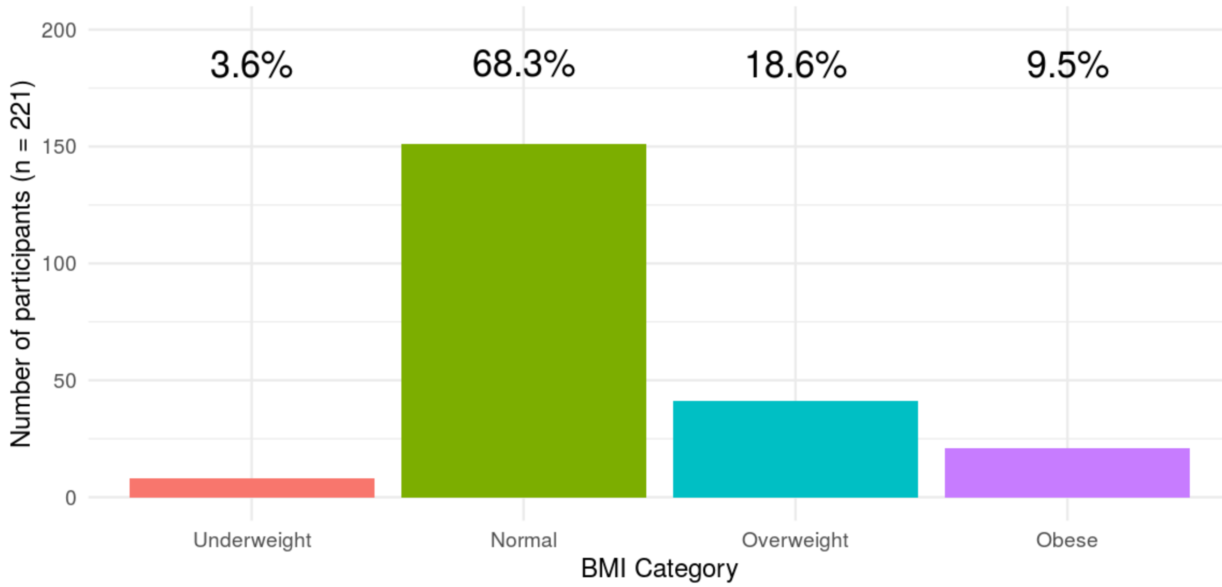
	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Age									
2. Height	-.03								
3. Weight	.19**	.32***							
4. BMI	.22**	-.09	.91***						
5. Fat (%)	.15*	.01	.81***	.85***					
6. Fat (kg)	.17*	.12*	.94***	.93***	.95***				
7. FFM	.18**	.54***	.85***	.66***	.40***	.61***			
8. Muscle Mass (kg)	.18**	.54***	.85***	.66***	.40***	.61***	1.00***		
9. SMM (kg)	.03	.58***	.67***	.46***	.14*	.38***	.95***	.95***	
10. SMM (%)	-.25***	-.01	-.80***	-.84***	-.99***	-.94***	-.39***	-.39***	-.12*

* $p < .05$, ** $p < .01$, *** $p < .001$

Body Mass Index. The final dataset resulted in 3D shapes from females varying in BMI from underweight to obese class II, with most of the bodies situated within the normal BMI category (68.30%, n = 151). The average BMI of this sample (*M* = 23.82) is in the normal BMI category, which is lower than the average BMI of women in the UK (27.50; overweight BMI category) and the average BMI for 16 - 44-year-olds (26.40; overweight) (HSE, 2018). The proportion of women in the overweight and obese categories make up 28.10% of the total sample, which means that these categories are underrepresented when compared to national data which report that around 50% of females aged 16 - 44 in the UK are classified as overweight or obese (HSE, 2018). In this sample, only 9.50% (n = 21) were classified as obese despite reports suggesting that 29% of women in the UK are obese (HSE, 2018). This percentage was slightly lower for Caucasian only women (27.50%) and women aged 18 - 44 (23%) (HSE, 2018). Despite a small proportion of the sample being underweight (3.60%, n = 8), this is comparable to and representative of national statistics suggesting that around 3.80% of women aged 16 - 44 are underweight (HSE, 2018). Figure 2.5 shows the distribution of this sample according to WHO BMI categories. Details of the WHO BMI categories are reported in Section 2.1.1.

Figure 2.5

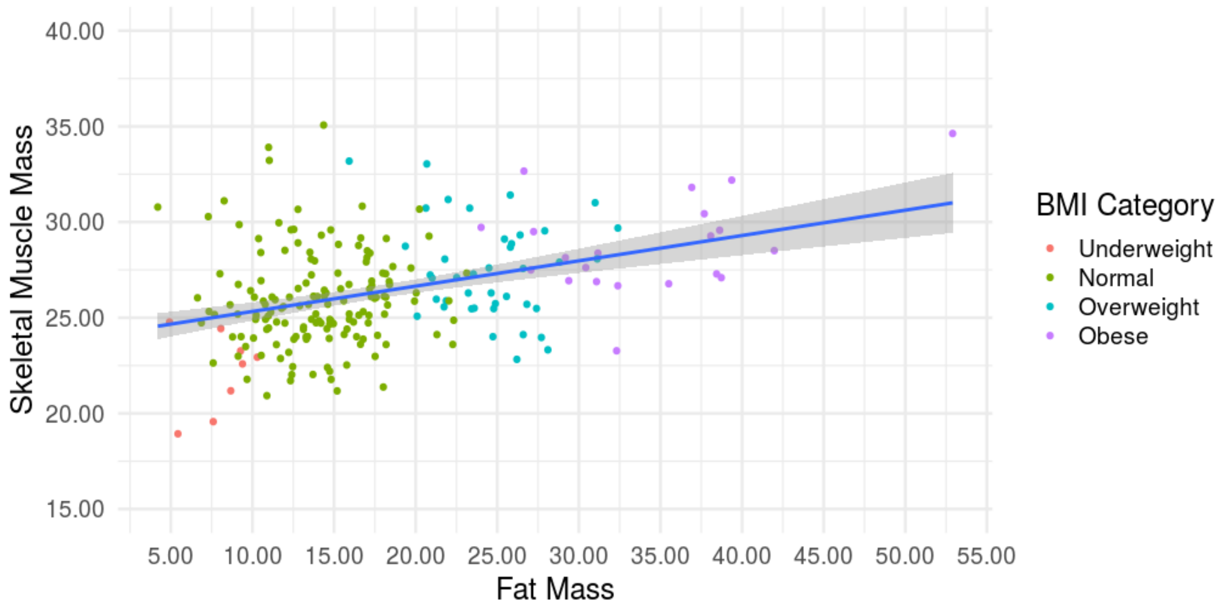
The percentage of the sample categorised according to WHO BMI categories.



The Relationship Between BMI and Body Composition (Fat and Skeletal Muscle Mass). There was a significant positive correlation between BMI and fat mass (in kg and percentage). There were also significant positive correlations between SMM and BMI/fat mass (in kg and percentage), suggesting that SMM is higher in those with higher BMI/body fat (see Table 2.5). Together, these findings are in agreement with previous research showing that BMI correlates with both fat and lean mass in adults (Romero-Corral et al., 2008). Figure 2.6 shows the relationship between SMM and fat mass with coloured points denoting the individual's BMI category.

Figure 2.6

The relationship between fat and SMM with coloured points denoting BMI category.



Within BMI categories, there were differences in the relationship between SMM and fat mass (kg), as demonstrated by the slopes in Figure 2.7. There were no significant correlations between fat and SMM for underweight (r = .16, p > .05, n = 8), normal weight (r = .01, p > .05, n = 151), and overweight (r = -.17, p > .05, n = 41) BMI categories, determined using Pearson's correlations. For the obese group there was a significant positive correlation (r = .39, p = .083, n = 21). The individual with the highest BMI/fat mass appeared to be an outlier in the obese category (see Figure 2.7), the relationship between fat and SMM was no longer significant once this individual was removed (r = .08, p > .05, n = 20). Nevertheless, the correlation between fat and SMM was still significant for the whole sample with this individual removed (r = .23, p < .001, n = 220).

Figure 2.7

The relationship between muscle and fat in each BMI category.

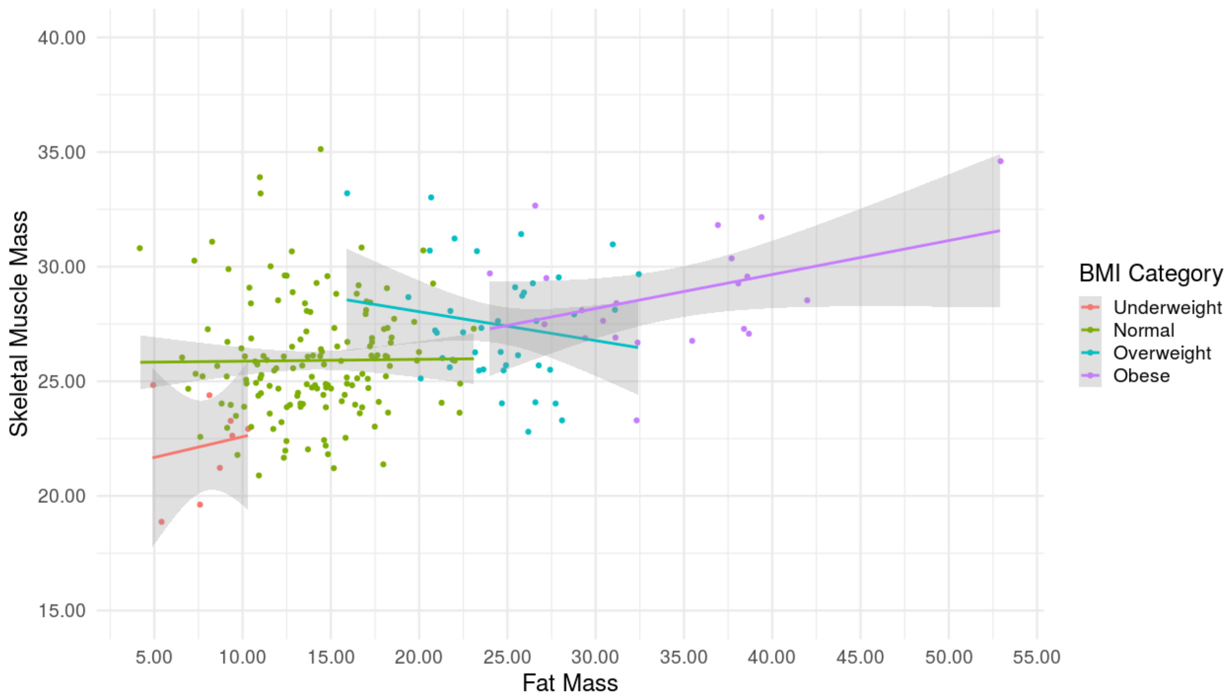


Figure 2.7 also demonstrates how body composition can vary within BMI categories, for example, in the normal weight category there is a large range of fat and SMM values (descriptive statistics for each BMI category are presented in Table 2.6). Furthermore, we can see that within a narrow range of body fat (e.g. 4.20 - 5.00 kg), there are large deviations in the individuals SMM (from 18.90 - 30.80 kg), which may skew BMI classification. For example, the individual with the lowest fat mass in this sample is considered a normal weight BMI (due to increased SMM), despite having lower fat mass than those in the underweight BMI category. Moreover, there is an overlap between the obese and overweight categories, where some individuals classed as obese have lower overall body fat than some individuals classed as overweight. This demonstrates how BMI classification does not differentiate body composition when focusing on weight alone and may misclassify some women.

Next, to determine whether there were significant differences between body composition variables in each BMI category, one-way ANOVAs were conducted (using Welch's ANOVA when homogeneity of variance was violated). Post-hoc comparisons of differences between each BMI category were conducted using Bonferroni corrected pairwise comparisons. There were significant differences in body fat percentage ($F(3, 217) = 125.90$, $p < .001$; all post-hoc comparisons ps $< .001$) and fat mass ($F(3, 28.64) = 192.35$, $p < .001$; all post-hoc comparisons ps $< .001$) between each BMI category. There were significant differences in SMM between BMI categories ($F(3, 217) = 18.19$, $p < .001$). Post-hoc comparisons revealed that there were differences between every category ($p < .005$), except between the overweight and obese groups ($p > .05$), suggesting similar levels of SMM for bodies in the overweight and obese BMI categories.

Table 2.6

Mean, standard deviation and range of body composition variables for each BMI category.

	Fat %		Fat Mass		SMM	
BMI Cat	*M* (SD)	Range	*M* (SD)	Range	*M* (SD)	Range
UW	17.30 (3.33)	10.70 – 20.60	7.96 (1.93)	4.90 – 10.30	22.21 (2.14)	18.90 – 24.80
NW	23.28 (4.58)	7.90 – 33.80	13.99 (3.60)	4.20 – 23.10	25.91 (2.51)	20.90 – 35.10
OW	32.84 (3.51)	21.70 – 38.70	24.53 (3.39)	15.90 – 32.40	27.46 (2.56)	22.80 – 33.20
OB	38.59 (3.74)	31.00 – 44.40	34.24 (6.63)	24.00 – 52.90	28.80 (2.54)	23.30 – 34.60

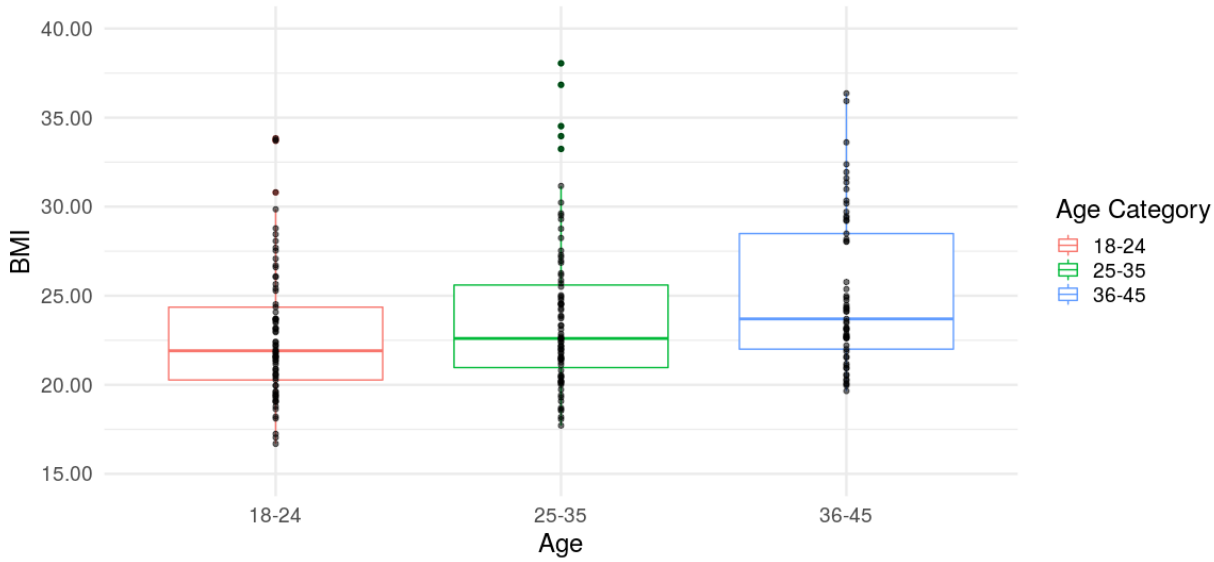
Abbreviations. Fat %, Body Fat Percentage; SMM, Skeletal Muscle Mass, UW = Underweight, NW = Normal Weight, OW = Overweight, OB = Obese

The Relationship Between Age, BMI, and Body Composition. This sample was limited to adults aged 18 - 45 to limit variation in body composition and shape that tend to occur as age increases. National data suggest that the prevalence of overweight/obesity increases with age and is higher above 45 years old (HSE, 2018). In this sample, there were significant positive associations between age, BMI, fat mass, and body fat percentage (see Table 2.5), indicating that body size and fat increases as age increases.

A one-way ANOVA revealed that there were significant differences in age between BMI categories ($F(3, 217) = 3.22$, $p = .024$). Post-hoc comparisons revealed that there was a significant difference between the mean age of the underweight ($M = 22.25$, $SD = 3.85$) and obese ($M = 32.48$, $SD = 7.61$) categories ($p = .015$), there were no significant differences between any of the other BMI categories ($p > .05$). When using similar age categories to HSE data, we can see that the mean BMI is 22.81 ($SD = 3.79$, n = 77) for 18 - 24 year olds, 23.80 ($SD = 4.25$, n = 83) for 25 - 35 year olds, and 25.13 ($SD = 4.28$, n = 61) for 36 - 45 year olds. The average BMI is in the normal BMI category for both 18 - 24 and 25 - 35-year-olds, but is just above the boundary of overweight for 36 - 45-year-olds. However, there are a large range of BMIs in each age group with overlaps between age groups (see Figure 2.8). A one-way ANOVA indicated that there were significant differences in BMI between age groups ($F(3, 218) = 5.34$, $p = .005$). There was a significant difference between the 18 - 24 and 36 - 45 age groups ($p = .003$), but no differences between the 18-25 and 25-35 or the 25-35 and 36-45 age groups (ps > .05).

Figure 2.8

Boxplots showing the distribution of BMI in this sample according to three different age groups (similar to the categories denoted in HSE data). The boxes denote the first and third quartile and the mid-line denotes the median BMI for each age group. The black points represent individual data points.



Similarly, for fat mass, a one-way ANOVA revealed there were significant differences in fat mass between age groups ($F(2, 218) = 3.15$, $p = .045$). Post-hoc comparisons revealed similar patterns to BMI, there was a difference between the fat masses of the 18-24 and 36-45 age groups approaching significance ($p = .054$), however, there were no differences between the other age groups ($p > .05$). There was no significant relationship between age and SMM ($r = .03$, $p > .05$) and a one-way ANOVA revealed there were no significant differences in SMM between age the age groups ($F(2, 218) = 0.35$, $p > .05$). This corroborates previous findings that SMM remains stable in adults 18-45 years old (Janssen et al., 2000) whereas fat increases, see Figures 2.9 and 2.10.

Figure 2.9

The relationship between age and fat mass.

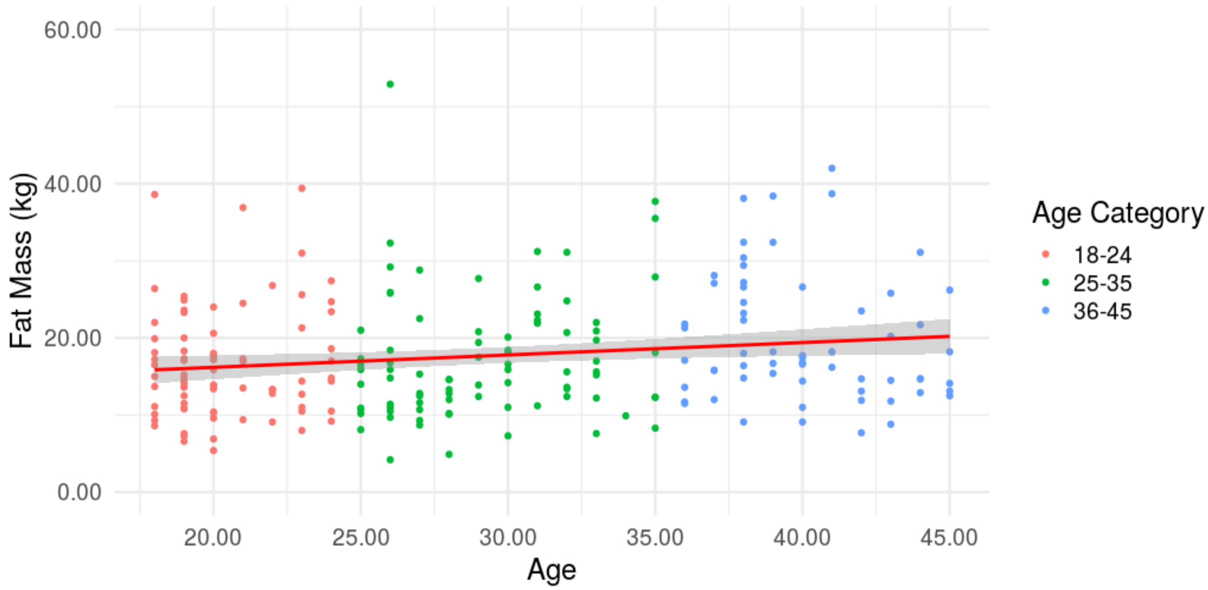
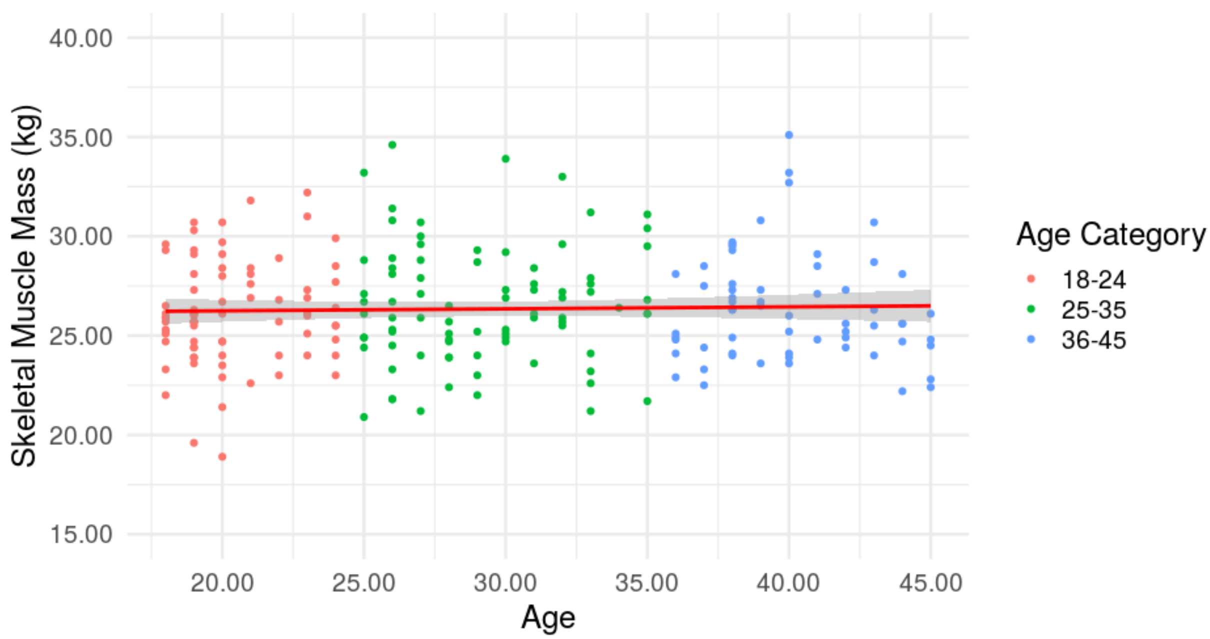


Figure 2.10

The relationship between age and SMM.



In conclusion, we have developed a 3D scan and body composition database consisting of 221 Caucasian women aged between 18 and 45 years old. We chose 3D scanning technology as it is an efficient tool for accurately capturing high-quality human body shapes from 360-degrees, which may be used as stimuli in research. The 3D shapes may be presented in 2D or 3D/life-size in virtual reality, with or without a photorealistic texture. Associated with each scan we also have information regarding each individual’s body composition, BMI, and age. Body composition was captured using BIA, when compared to the calliper methodology we found a small (1.27%) non-significant difference for body fat percentage between the two methods, and good test-retest reliability for a range of body composition variables (see Section 2.1.3).

Furthermore, the relationship between these body variables and how they compare to national statistics in the UK was explored. In this sample of women, we found that body composition varied as a function of BMI category and age. The findings indicate that SMM remains stable throughout 18 - 45-year-olds, as found in previous research, but tends to be associated with BMI and fat mass (Janssen et al., 2000; Lafortuna et al., 2014; Tomlinson et al., 2014). There were increases in BMI and fat mass associated with age in this sample, 36 - 45-year-olds had a significantly higher BMI than 18 - 24-year-olds, and those in the obese BMI category were significantly older than underweight participants. This supports HSE data which posits that 16 - 24-year-olds were least likely to be overweight/obese, whereas the prevalence of overweight/obese was 70% and above for age groups above 45 (HSE, 2018). The relationship between fat and SMM differed between BMI categories, as demonstrated by the slopes in Figure 2.7. Skeletal muscle mass tended to increase with BMI but remained stable for the overweight and obese BMI categories. These findings indicate that whilst body mass increases with age, this is typically an increase of fat, not SMM. These findings revealed that solely focusing on BMI when creating stimuli for body perception tasks may ignore deviations in body composition that can occur both across and within BMI categories. Within BMI categories we can see the women vary greatly in their amount of fat and muscle (shown in Figure 2.7 and Table 2.6), demonstrating that two individuals may have similar BMIs but different body compositions. Those with higher SMM can be misclassified by BMI as it only considers total mass and does not distinguish between fat and muscle.

While this database captures a wide range of body size/shapes, there is still an overrepresentation of those within the normal BMI category. The data suggests that this database underrepresents overweight/obese bodies, compared to national statistics. This may be due to the sensitive nature of the project, as participants were asked to wear underwear and have their body measurements taken. In future, it would be beneficial to increase the representation of overweight, obese, and underweight female bodies, to ensure that we are fully capturing body sizes/shapes that are representative of women in the UK. Moreover, it would also be beneficial to expand the diversity of scans at the extremes of fat and SMM. Expansion of the dataset means that a wider variety of body sizes/shapes are captured which will enable a greater understanding of the relationship between 3D body shape and body composition. This will also ensure that future stimuli developed using this database fully captures shape variation that is representative of a wide range of BMIs, fat and skeletal muscle masses.

A selection of the 3D body shapes is used in Chapter 5 to assess perceptions of BMI categories. In Chapter 6, the database is used to create and assess novel 3D body stimuli that were statistically calibrated for fat and SMM.

Chapter 3: (Studies 1 & 2): Investigation of a Novel Body Size Perception Intervention, and the Relationship Between Perceptual Body Image, Psychological Concerns and Categorisations of Body Size

3.1 Introduction

In Chapter 1, the clinical manifestation of body image disturbance and the importance of developing effective interventions for those with clinical and subclinical levels of eating and body image disturbances was discussed. Interventions specifically targeting body image disturbances have become increasingly recognised as an effective component of treatments and interventions (Alleva et al., 2015; Farrell et al., 2006; McLean & Paxton, 2019; Stice & Shaw, 2002), including targeting general misperception of body size/shape (Challinor et al., 2017; Moody et al., 2017; Tovée et al., 2000).

The purpose of this current research (Study 1) was to first explore the replicability of the Cognitive Bias Modification (CBM) intervention developed by Gledhill et al. (2017) to manipulate categorical perceptions of thinness (discussed in more depth in Section 1.4.1, Chapter 1), in a sample of women with high body, weight, and shape concerns but no current diagnosis or history of an eating disorder. Previous findings indicate that the intervention successfully manipulated categorical perceptions of ‘thin’ and ‘fat’ bodies, where the boundary between thinness and fatness was higher in BMI post-intervention, and psychological concerns related to body image and disordered eating were reduced post-intervention for those in the intervention group, with both the perceptual and psychological effects maintained for up to 2-weeks (Gledhill et al., 2017; Irvine et al., 2020). Another study also found that there was an increase in the BMI of the most ideal and attractive body size post-intervention for those in the intervention group but not the control group and this was maintained at the 2-week follow up (Szostak, 2018).

Moreover, in this study, an extension of the Gledhill et al. (2017) CBM intervention was conducted by including an additional follow-up at day 30, as well as the 2-week follow-up included, to assess the longer-lasting effects of this intervention. Some authors have suggested that only measuring symptomology at a single time point 14-days post-treatment fails to capture variability (Williams et al., 2012) and a 28-day follow-up has been recommended as a widely accepted timeframe for follow-up (Linardon & Wade, 2018). Szostak (2018) concluded that further investigation of the intervention with more intensive training and longer follow-ups should be explored, particularly when using a clinical or subclinical sample whom might be more resistant to change. This helps to further understand the therapeutic and clinical utility of the intervention by determining whether perceptual and psychological effects are maintained for up to 30 days.

Furthermore, whilst reductions in attitudinal body image disturbances have been demonstrated post-intervention (Gledhill et al., 2017; Irvine et al., 2020; Szostak, 2018), there have been no studies investigating whether this CBM intervention targets perceptual body image disturbance related to the individual. If the perception of a 'thin' body is shifted higher up in the BMI spectrum, one might expect to see changes in self-perceived body size/shape towards reduced misperception, associated with changes in the perception of what is a 'normal' body size (Challinor et al., 2017). There may also be increases in ideal body size/shape, in line with Szostak's (2018) findings. Therefore, an interactive assessment of self-perceived and ideal body size/shape was additionally included at day 1 (baseline) and day 30 (post-intervention), where participants could alter a 3D model on a set of size and shape dimensions. This allows a more in-depth understanding of how targeting general perceptions of thinness/fatness relates to an individual's perception of their own perceived current and ideal body size/shape.

Lastly, whilst previous work has found the CBM task successfully alters categorical perceptions of body size in women with heightened body dissatisfaction, it is unclear how categorical perceptions of body size (and the shifting of) directly relates to an individual's own body image (both perceptual and attitudinal), and whether those with lower dissatisfaction categorise similarly. Therefore, in this Chapter the interactions between psychological/body concerns, categorical perceptions of body size, and perceptual body image (perceived and ideal body size/shape) were explored to develop understanding of the relationship between these different components in women with heightened body concerns (Study 1) and in women with low/mild body concerns (Study 2). In Study 2, baseline measures of perceived and ideal body size/shape, categorical judgements of body size, and psychological symptomology, between women with heightened and low/mild body concerns were compared. This was to enable further understanding of the relationships between the different components, and whether these relationships differ as a function of body concerns.

Study 1: Investigating the Effectiveness of a Cognitive Training Program in Women with High Body Concerns

3.2 Method

Ethical approval was gained from the School of Psychology Research and Ethics Committee at the University of Lincoln (Project code: PSY1718455).

3.2.1 *Aim*

The main aim of this study was to investigate the effectiveness of a body size CBM intervention in a non-clinical sample of females with high body concerns. The following hypotheses were made:

1) The perceptual and psychological outcomes by Gledhill et al. (2017) would be replicated, such that the thin/fat categorical boundary would increase (i.e. less bodies considered fat) and psychological concerns would decrease post-intervention for those in the intervention group.
2) The perceptual and psychological outcomes (increased thin/fat categorical boundary and decreased psychological concerns) for those in the intervention group would be maintained at the two-week follow up, as in Gledhill et al. (2017), and would also be maintained at the 30 day follow up.
3) There would be a shift in perceptions of perceived and ideal body size/shape post-intervention for those in the intervention group, such that there would be an increase in ideal body size/shape and perceived body size/shape would become more accurate (closer to actual body size/shape).

3.2.2 *Participants*

Thirty-eight women participated in the study, recruited using advertisements around the University and city centre, social media posts, and word of mouth. Only women aged 18 and above, scoring over 60 in the Body Shape Questionnaire (BSQ 16b) and with no history of an eating disorder were eligible to take part. Prior to participation in the study, potential participants were screened online using a Qualtrics form, which included the BSQ to determine those with high body, weight, and shape concerns and demographic questions (sex, age, and diagnosis of an eating disorder). The estimated sample size based on data from Gledhill et al. (2017) suggests that appropriate sample size estimates were 19 or 20 per condition (Irvine et al., 2020). Pre-screening responses were collected from 243 individuals, of which 74 were eligible and 39 agreed to take part. One participant withdrew from the study resulting in the final sample of 38 participants. The sample was predominantly Caucasian (84.21%) with 10.53% identifying as Asian and 5.26% as a mixed ethnicity. Participants received a £30 cash payment or course credits for participation. The participant's characteristics are displayed in Table 3.1. There were no significant differences between the intervention and control conditions (all *p*s > .05).

Table 3.1

Descriptive statistics (mean, standard deviation, and range) of participant characteristics and BSQ (pre-screening) scores, for the whole sample and each condition separately.

	Intervention (n = 19)	Control (n = 19)	Overall (n = 38)		Int vs Con
	M (SD)	*M* (SD)	*M* (SD)	Range	*p*
Age	22.84 (8.17)	23.58 (7.91)	23.21 (7.94)	18.00 - 48.00	.690
BMI at Day 1	28.13 (5.90)	28.41 (5.35)	28.27 (5.56)	19.79 - 41.96	.876
BMI at Day 30	28.01 (5.98)	28.41 (5.34)	28.21 (5.59)	19.68 - 42.24	.828
BSQ	69.95 (7.00)	72.68 (9.47)	71.32 (8.33)	60.00 - 96.00	.318

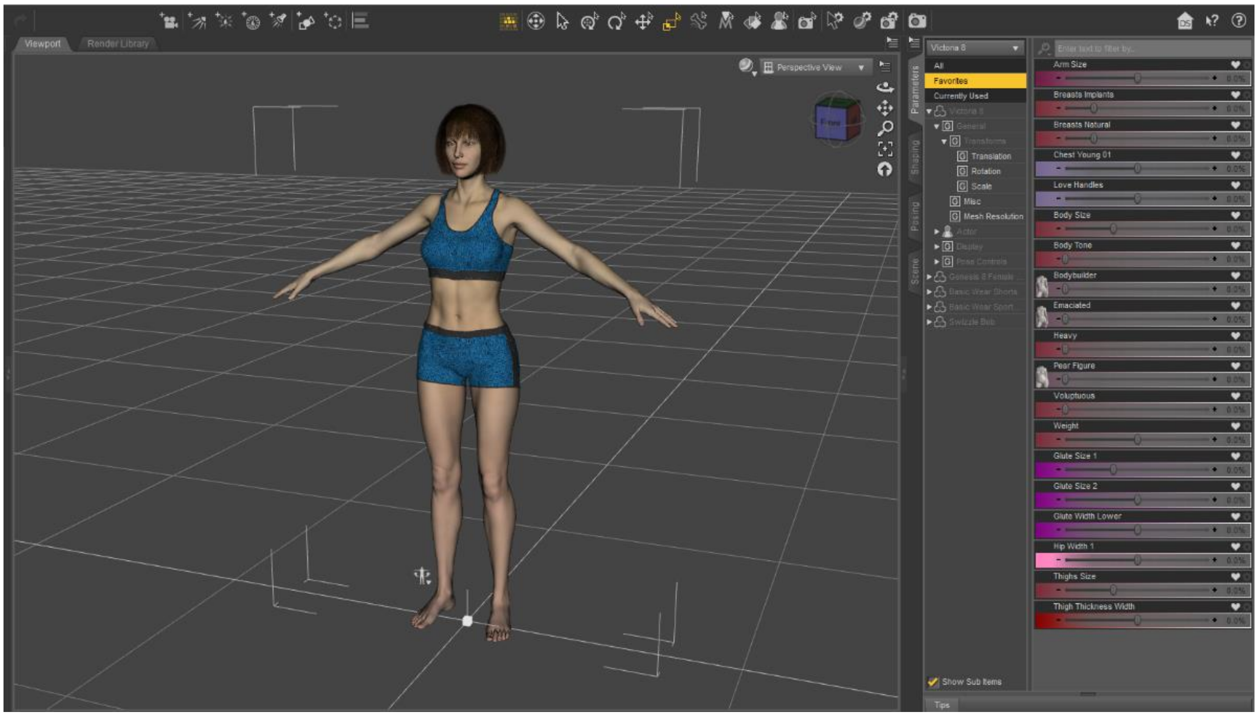
Abbreviations. Int = Intervention Group, Con = Control Group.

3.2.3 *Materials*

Interactive 3D Body Size and Shape Estimates. Participants were asked to create their perceived current (as close as possible to the body size/shape that represented how they looked as of that day) and ideal (as close as possible to the body size/shape they would ideally like to have) body size/shape, using 'Daz3D Studio' software (v. 4.10; Daz3D.com). Using this software, participants were presented with a 3D female model wearing a sports bra and shorts ('Victoria 8', Genesis 8 model, which is a widely used model provided by Daz3D.com) (see Figure 3.1). The body size/shape of the model could be manipulated using a range of full body (e.g. weight, body size, tone) and body-part specific (e.g. upper arm size, thigh size, waist width, breast size) sliders, to create a personalised estimation of body size/shape. See Appendix C (Table C.1) for a full list of the sliders that were used. Manipulating these sliders changed the body size/shape of the model in real-time. Participants were first shown an example model and the effects of increasing/decreasing each slider before creating their estimates. To minimise anchoring effects from the starting body size/shape as a factor which may influence size/shape estimations (Probst et al., 1992), two different starting bodies were used and an average was taken (Gardner, 1996). Tables C.1 and C.2 (Appendix C) present details of the two starter bodies and the starting position of the sliders available for participants to use. The order in which participants created their estimations (either perceived current or ideal) was randomised prior to participation, as was the order of the starting body size/shape for each estimation. Participants instructed the researcher which sliders to manipulate and by how much until they were satisfied with their estimates. This method has been shown to have good test-retest consistency (Crossley et al., 2012).

Figure 3.1

The Genesis 8 Female 3D model used for interactive body size/shape estimations, using Daz Studio software.



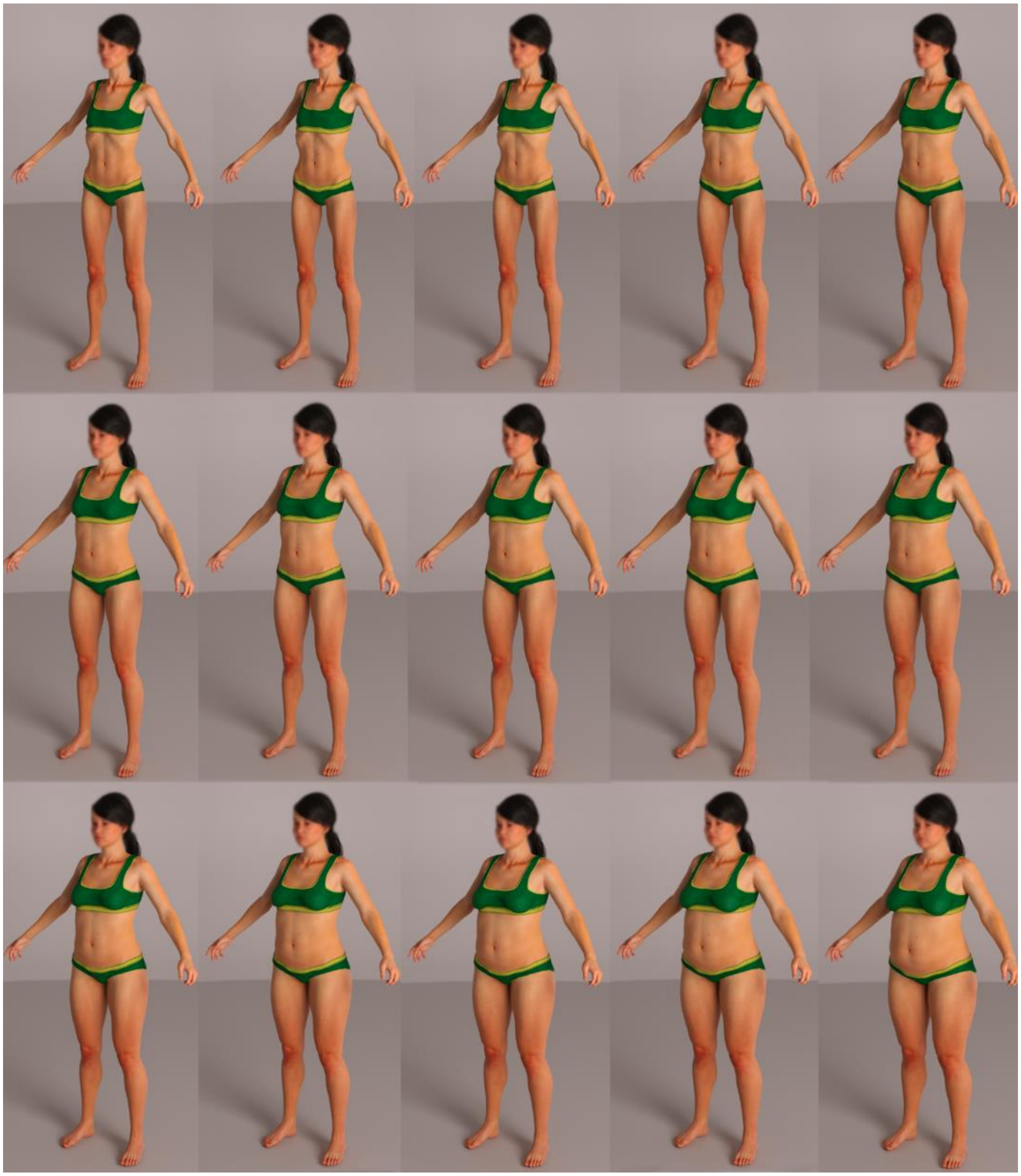
Psychometrics. A series of validated questionnaires were used to assess attitudinal body image and psychological concerns, including eating disorder psychopathology, body dissatisfaction, internalisation of body ideals, self-esteem, and depressive symptoms (see Section 2.2, Chapter 2). For the BSQ, EDE-Q, RSES, BDI, SATAQ-4 Thin-ideal internalisation, and SATAQ-4 Athletic-ideal internalisation, Cronbach's alpha for this sample was .93, .93, .91, .90, .82, and .92, respectively.

Body Stimuli. The stimuli used in the CBM protocol were a series of computer-generated female bodies created using 'Daz3D Studio' (v. 4.80; Daz3d.com). A Genesis 2 base model with the "Victoria 6" character skin was used to create the female model. The shape of the body was calibrated based on Health Survey for England (HSE) data to represent that average shape of a

Caucasian female in the UK. For more information on the development of these stimuli, see Cornelissen (2016). In this study, 15 bodies ranging from 15.36 (underweight) to 33.56 (obese) BMI units with the face area blurred were used, based on data collected by Gledhill (2015) as best capturing the range from categorically ‘thin’ to ‘fat’. See Figure 3.2 for the range of stimuli used in this study.

Figure 3.2

The full range of computer-generated stimuli ranging from a BMI of 15.36 (underweight, top left) to 33.56 (obese, bottom right).



The CBM Task. There were three phases involved in the body size perception training program: baseline, training and test.

Baseline. This was used to identify each participant's baseline categorical perception of body size. During the baseline sequence, participants were shown each of the 15 images three times (45 trials in total) in random order and were asked to respond by pressing a key whether they considered the body to be 'thin' or 'fat' ('c' = thin; 'm' = fat). The individuals' categorical boundary was then derived by dividing the number of times the participant responded 'thin' by the number of trials and multiplying by the number of stimuli e.g. (25 / 45 * 15 = 8.33) (i.e. a categorical boundary corresponding to body 8, a BMI of 21.37). The higher the categorical boundary, the more bodies the participant categorised as 'thin' and the less categorised as 'fat'.

Training. The training sequences (employed on days 1 – 4) followed a similar format as the baseline sequences, with the addition of feedback after the key response e.g. "Correct! That body was thin." There were 31 trials in six blocks (186 trials in total). As some body sizes were more ambiguous than others, they were shown more often than the ones that were less ambiguous (more consistently categorised as 'thin' and 'fat'). Bodies 1, 2, 14 and 15 were displayed once, bodies 3 - 5 and 11 - 13 were displayed twice, and bodies 6 - 10 were displayed three times in each block. Feedback was based on each participant's baseline boundary on each day.

Intervention vs control condition. Participants were assigned to either a control or intervention condition which was randomly pre-determined prior to participation.

In the intervention group participants were given inflationary feedback during the training phase to shift their thin/fat categorical boundary by two bodies along the body sequence (from a lower to a higher BMI), so that bodies previously categorised as 'fat' would be considered 'thin' post-training. For example, if a participant responded 'fat' to a body stimulus that was within +2 of their categorical boundary they would get the response "Incorrect! That body was thin." In the control condition participants received feedback that was consistent with their baseline categorical boundary, to reinforce their categorical judgements rather than trying to shift them.

Test. In the test phase (immediately after training), the participants completed the baseline sequence again to determine their post-training categorical boundary.

For each phase, the same presentation timings as Penton-Voak et al. (2013) and Gledhill et al. (2017) were used. Participants were first shown a fixation cross for 1500 - 2500ms (randomly jittered), followed by the body stimuli for 150ms in a random order, then a mask of visual noise for 150ms, followed by a '?' which prompted participants to respond whether the body was 'fat' or 'thin', with no time restriction.

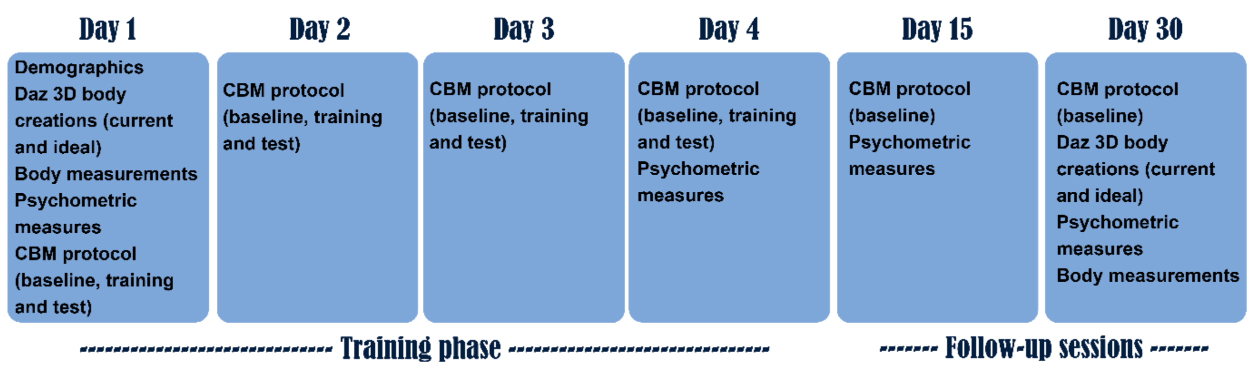
Body Measurements. Estimates of body composition and BMI were taken using the Tanita BIA scale, standing height using a stadiometer, and circumference measurements (waist, hip, and bust) using a tape measure (see Section 2.1, Chapter 2).

3.3 Procedure

Participants were screened for body concerns using the BSQ (16b) on Qualtrics, after providing informed consent. Only women aged 18 and above, scoring over 60, and with no current diagnosis or history of an eating disorder were eligible to participate. Those who were eligible were invited into the lab to take part in the training and follow-up sessions, which consisted of six sessions across 30 days. The training phase was run across four consecutive days, with follow-up sessions on days 15 (two-weeks from the first session) and 30. Measures of psychological symptomology were administered on day 1 (baseline), after the training phase on day 4, and on the follow-up sessions (days 15 and 30). The participant's actual body measurements and interactive 3D body size/shape estimates were measured at baseline on day 1 and on the final follow-up session (day 30), except height which was only taken at day 1. The computer tasks were completed on a 21.5" flat-panel LCD screen with a resolution of 1920 by 1080 pixels in a university lab. Participants were debriefed after their final session. See Figure 3.3 for an overview of the full procedure.

Figure 3.3

An overview of the tasks completed on each day of the study.



3.4 Data Analysis

Analyses were conducted using ‘R Studio’ (R Version 4.0.2).

Categorical Boundary

Baseline (pre-training) and test (post-training) boundaries for each participant were converted to a BMI value, since each body stimulus is associated with a BMI value. Each individual’s categorical boundary was rounded to the nearest corresponding stimulus BMI, following the same approach as Gledhill et al. (2017) and Irvine et al. (2020). For example, if a participant’s categorical boundary was 8.33, this would correspond to stimulus 8 which has a BMI of 21.37.

Interactive 3D Body Size/Shape Estimations

As each body estimation was created twice using two different starter bodies (one underweight and one obese), measurements were determined for each body estimation (perceived current and ideal) and an average was used for all analyses. The 'measure metrics' tool in Daz Studio software allows for measurements to be taken that are scaled 1:1 with the real world using a series of digital tape measures. Each body was first scaled to match the participant's height (within +/- .30cm) and circumference measurements for waist, low hip and bust were taken to two decimal places (cm).

Four variables were considered for this analysis: BMI, waist-to-hip ratio, waist-bust-ratio and bust-to-hip ratio, outlined below.

BMI - the estimated BMI was calculated using a calibration equation outlined by Cornelissen (2016) and in Section 2.3, Chapter 2 of this thesis, using the hip and waist circumferences from the body estimation and the height and age of the participant.

Waist-to-Hip Ratio (WHR) – calculated by dividing the waist circumference by the hip circumference. A lower WHR value indicates a smaller waist relative to hips/buttocks, representing a more curvaceous lower body shape. A higher value indicates a straighter/less curvaceous lower body, where there is less difference between the waist and hips/buttocks.

Waist-to-Bust-Ratio (WBR) – calculated by dividing the waist circumference by the bust circumference. A lower WBR indicates that the bust is larger relative to the waist, representing a more curvaceous upper body. A higher WBR indicates that there is less difference between the two or that the bust is smaller than the waist.

Bust-to-Hip Ratio (BHR) – calculated by dividing the bust circumference by the hip circumference. A lower BHR indicates a ‘pear-shaped’ figure where the hips/buttocks are larger compared to the bust, whereas a higher BHR indicates a ‘top heavy’ figure where the bust is larger compared to the hips/buttocks.

For each body size/shape variable, two new body estimation variables were calculated:

Perceptual Body Dissatisfaction (BD) – calculated as the difference between the ideal body and the perceived current body (ideal – perceived current). A negative value indicates a desire for a smaller/decreased ideal body size/shape compared to the perceived, 0 indicates no difference between ideal and perceived body size/shape, and a positive value indicates a desire for an ideal body size/shape that is larger/increased compared to the perceived.

Body Image Distortion (BID) – calculated as the difference between the perceived current and actual body (perceived current – actual). A negative value indicates underestimation (that the perceived is smaller/decreased compared to the actual), 0 indicates no difference between the perceived and the actual body size/shape variable, and a positive value indicates overestimation (that the perceived is larger/increased compared to the actual).

Missing Data

There were missing data for one participant in the intervention group at the two-week follow-up (day 15), which was therefore omitted from all analyses. Her data for the remaining sessions were included as she completed all training sessions, resulting in a sample of 37 (n = 18 for the intervention group) on day 15 only.

3.5 Results

3.5.1 *Participant Characteristics*

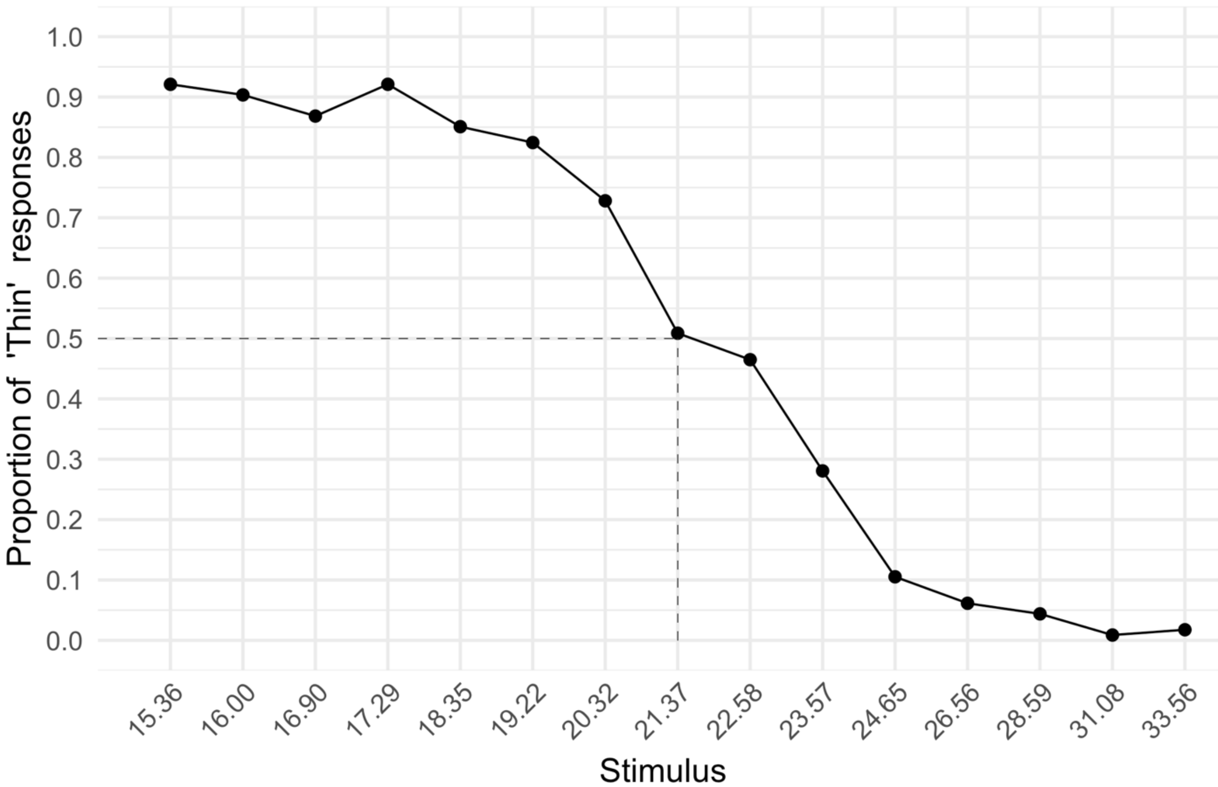
A series of 2 (Day: 1 vs 30) X 2 (Condition: Intervention vs Controls) ANOVAs revealed that there were no significant effects of condition or day on BMI, BHR, or WBR (all ps > .05). For WHR, there was a significant main effect of condition ($F(1,72) = 7.46$, $p = .008$), such that the women in the intervention group had a significantly higher WHR on both day 1 and 30. There was no significant difference between the intervention and control groups height, determined using a Wilcoxon Signed-Rank Test ($p > .05$). This indicates that the body measurements did not significantly differ from day 1 to 30 and were similar across conditions, except for WHR. See Appendix C for descriptive statistics of body measurements.

3.5.2 *Categorical Boundary*

First, the proportion of all participant's baseline responses on day 1 which were 'thin' for each stimulus was calculated. The proportion of 'thin' responses decreased as stimuli increased in BMI. As demonstrated in Figure 3.4, underweight stimuli (BMIs 15.36 – 18.35) were typically categorised as 'thin' (more than 85% of the time) and overweight/obese stimuli (BMIs 26.56 – 33.56) were typically categorised as 'fat' (more than 93% of the time). The stimulus with a BMI of 21.37 was categorised as 'thin' approximately 50% of the time, indicating ambiguity. These findings are similar to responses obtained by Gledhill (2015).

Figure 3.4

The proportion of 'thin' responses for each stimulus during the baseline sequence on Day 1, where the grey dotted line indicates the BMI at which 50% of responses were 'thin'.



The means and standard deviations of the baseline/pre-training and test/post-training categorical boundaries for each group (intervention and control) and each day of participation are presented in Table 3.2. The intervention groups categorical boundary increased from 20.63 at baseline (low normal BMI) to 25.48 post-training (the boundary of overweight) and it remained above 25 at both follow-up dates. For the control group, there was a smaller increase in their categorical boundary from 21.24 (low normal BMI) to 23.68 post-training (normal BMI) and it remained around 23 BMI units at both follow-up dates.

Table 3.2

The baseline/pre-training and post-training categorical boundaries for both interventions and control groups, separately for each day.

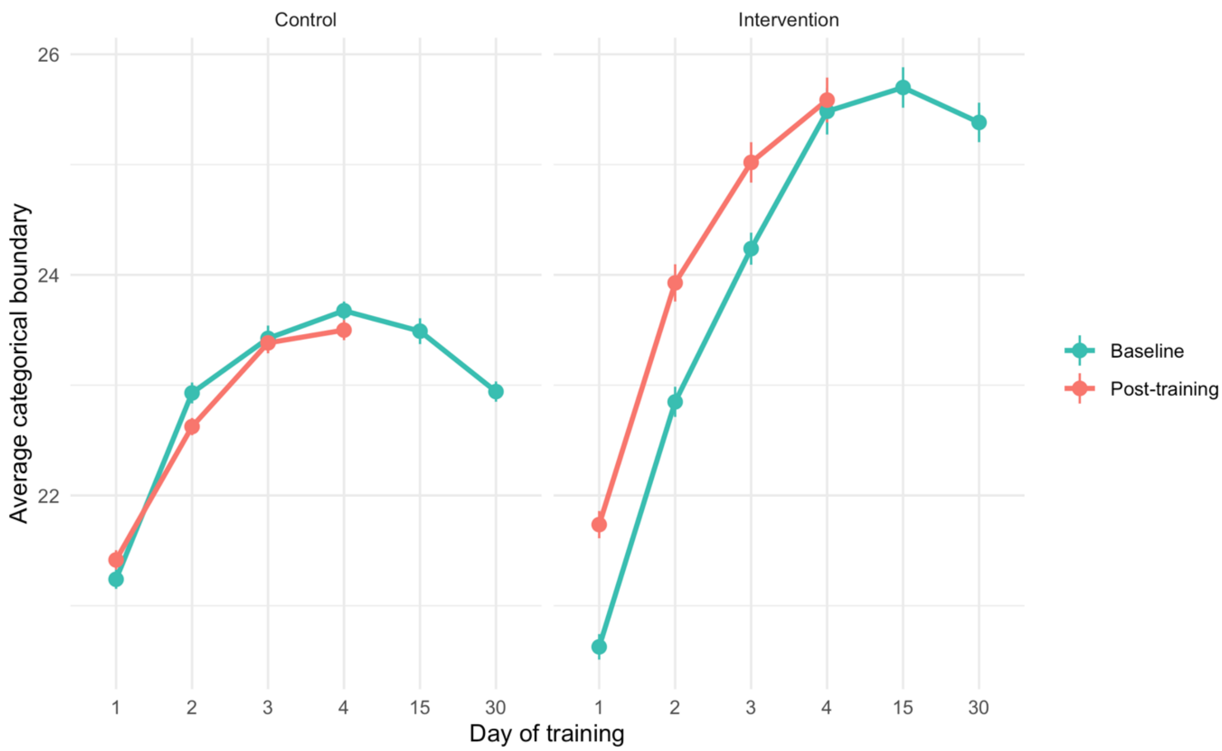
Condition	Boundary	Day 1	Day 2	Day 3	Day 4	Day 15	Day 30
		M(SD)	*M*(SD)	*M*(SD)	*M*(SD)	*M*(SD)	*M*(SD)
Intervention	Pre	20.63 (2.19)	22.85 (2.60)	24.24 (2.76)	25.48 (3.98)	25.70 (3.30)	25.38 (3.40)
	Post	21.74 (2.35)	23.93 (3.21)	25.02 (3.48)	25.59 (3.87)	-	-
Controls	Pre	21.24 (1.65)	22.93 (1.80)	23.42 (2.21)	23.68 (1.59)	23.49 (2.22)	22.94 (1.75)
	Post	21.42 (1.68)	22.62 (1.49)	23.38 (1.80)	23.50 (1.73)	-	-

Abbreviations. Pre = pre-training (baseline) categorical boundary, Post = post-training (test) categorical boundary (only applicable to days 1 – 4).

The difference between pre-training (calculated from responses in the baseline phase) and post-training (calculated from responses in the test phase) categorical boundary was analysed, where a positive difference indicated an increase post-training (i.e. less bodies were considered ‘fat’) and a negative difference indicated a decrease post-training (i.e. more bodies were considered ‘fat’). The post-training categorical boundary increased for both groups on day 1 but more so for the intervention group, indicating that less bodies were considered ‘fat’. The change diminished as the days went on and even became negative for the control group, which means they considered more bodies as fat in the test phase (post-training). A 2 (Condition: Intervention vs Controls) X 4 (Day: 1, 2, 3, 4) ANOVA revealed that there was a significant main of effect of condition, such that there was a higher mean difference between pre- and post-training boundaries for the intervention group ($F(1,144) = 11.69$, $p < .001$). Post-hoc independent t-tests for each day were conducted: Day 1 ($t(35.62) = -2.33$, $p = .025$) (Intervention, $M_{\text{Diff}} = 1.11$, $SD = 1.29$; Control, $M_{\text{Diff}} = 0.18$, $SD = 1.17$); Day 2 ($t(31.92) = -3.00$, $p = .005$) (Intervention, $M_{\text{Diff}} = 1.08$, $SD = 1.66$; Control, $M_{\text{Diff}} = -0.30$, $SD = 1.14$); Day 3 ($t(34.72) = -1.47$, $p > .05$) (Intervention, $M_{\text{Diff}} = 0.78$, $SD = 1.56$; Control, $M_{\text{Diff}} = -0.04$, $SD = 1.89$); Day 4 ($t(29.30) = -0.50$, $p > .05$) (Intervention, $M_{\text{Diff}} = 0.10$, $SD = 2.09$; Control, $M_{\text{Diff}} = -0.18$, $SD = 1.24$). These findings revealed that on days 1 and 2, the difference between pre- and post-training categorical boundary was significantly higher for the intervention group. However, for days 3 and 4, despite the boundary for the intervention group increasing, this was not statistically different to controls. Figure 3.5 displays the means and standard error of the thin/fat categorical boundaries for each day and condition.

Figure 3.5

Categorical boundary (mean and standard error) for each day and condition.



3.5.3 *Linear Mixed-Effects Models of the Thin/fat Categorical Boundary*

Linear mixed-effects models were used to predict participant's categorical boundary using the 'lme' function from the 'nlme' package (Version 3.1-148; Pinheiro et al., 2020). Two models were conducted, the first considering baseline categorical responses on each day of participation and the second considering pre- and post-training categorical boundaries on the training days (1, 2, 3, 4). Firstly, to determine whether permitting random variation for each participant was warranted, intercept only models were compared to random intercept only models allowing variation from participants. The models including a random intercept for participants were considered a better model fit due to decreased AIC/BIC values and a significant reduction in log-likelihood (ps < .001).

Linear Mixed-Effects Model of Baseline Categorical Boundary.

$$y_i = \beta_0 + \beta_1 x_1 * \beta_2 x_2 + u_{j1} + \epsilon_{ij1}$$

y_i = Baseline Categorical Boundary, x_1 = day (1, 2, 3, 4, 15, 30), x_2 = condition (intervention or control), u_{j1} = random intercept of the participant (participant ID) and ϵ_{ij1} = residual error.

Day was entered as a categorical variable with six levels (1, 2, 3, 4, 15, and 30) and condition with two levels (intervention and controls) as baseline boundaries were calculated for each participant on each day of participation. The model revealed that there was a significant Type III main effect of day ($F(1,179) = 8.82$, $p < .001$), but no significant main effect of condition ($F(1,36) = 0.57$, $p > .05$). There was significant day X condition interaction ($F(1,179) = 9.21$, $p < .001$). The 'r.squaredGLMM' function from the 'MumIn' package (Version 1.43.17; Bartoń, 2020) was used to calculate conditional R^2 for the model ($R^2 = .80$), showing that the model explained approximately 80% of the variance in the data. A full model summary can be found in Table C.4, Appendix C.

The 'emmeans' function from the 'emmeans' package (Version 1.4.7; Lenth et al., 2020) was used to calculate predicted means and to complete pairwise comparisons, corrected for multiple comparisons using the Tukey method of adjustment.

The intervention group had significantly higher baseline categorical boundaries on days 2, 3, 4, 15 and 30 compared to their baseline on day one (ps < .001). The mean difference between days 1 and 4 = 4.86, days 1 and 15 = 5.24, and days 1 and 30 = 4.76. Compared to day 4 baseline, there was no significant difference between baseline boundaries on days 15 and 30 (ps > .05).

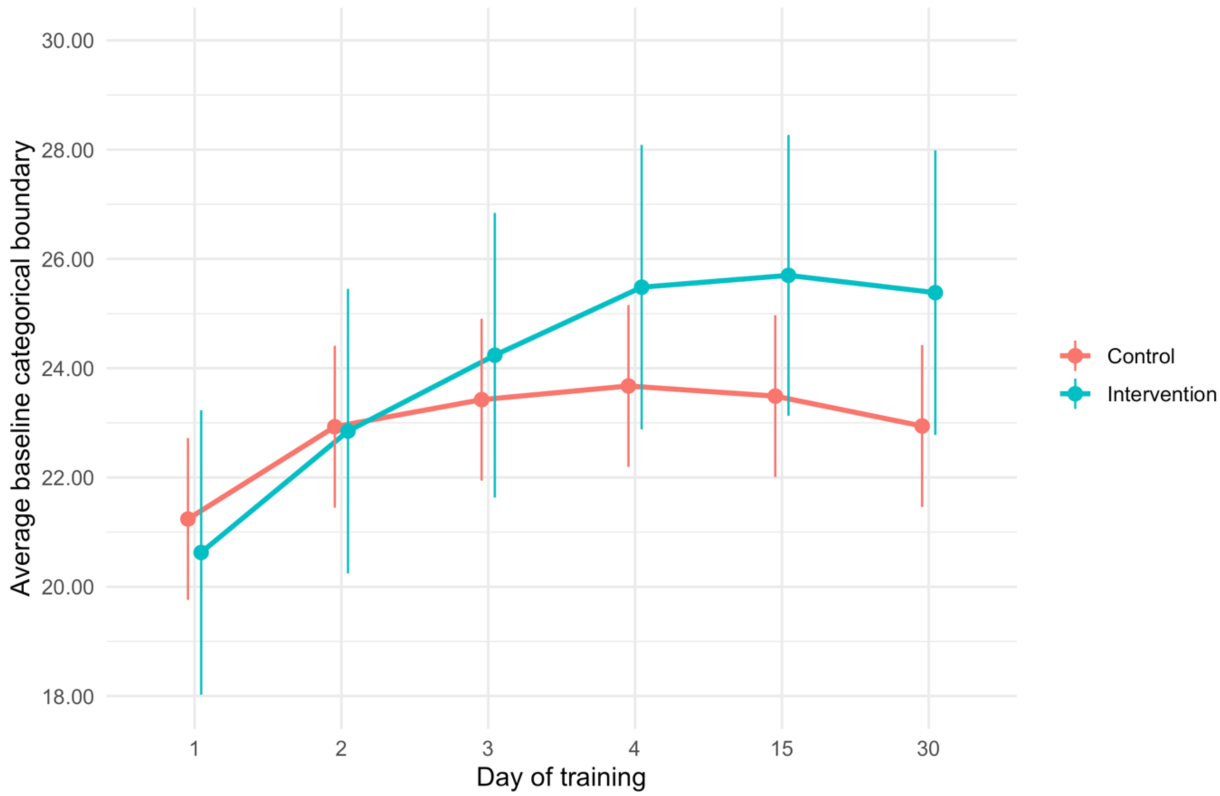
There were small mean differences between days 4 and 15 = 0.39 and days 4 and 30 = 0.10. Together, these findings indicate that there was a shift in the BMI of the thin/fat categorical boundary by around 5 BMI units over the course of training and that this was maintained at both follow-up days, such that the thin/fat boundary increased by 5 BMI units from 20.63 (low end of the normal BMI range) on day 1 to 25.48 – 25.87 BMI (the boundary of the overweight BMI category) on days 4/15/30.

The control group also had significantly higher baseline categorical boundaries on days 2, 3, 4, 15 and 30 compared to day 1 (all ps < .008). The mean differences were smaller than for the intervention group. The mean difference between days 1 and 4 = 2.45, days 1 and 15 = 2.25, and days 1 and 30 = 1.70. Compared to day 4, there was no significant difference between baseline on days 15 and 30 (ps > .05). The mean differences between days 4 and 15 = 0.19 and days 4 and 30 = 0.73 were small. These findings indicate that there was a small shift in the BMI of the thin/fat categorical boundary by around 2 BMI units over the course of the study, such that the thin/fat boundary at baseline was 21.24 (low end of normal BMI range) on day 1 and was between 22.94 - 23.68 on days 4/15/30 (middle of normal BMI range).

The baseline categorical boundaries of the intervention and control groups did not significantly differ on any day (ps > .05), suggesting that although the intervention group showed a larger change in baseline categorical boundary across the course of the study, their thin/fat boundary was not significantly higher than the control group, on average. Figure 3.6 presents the predicted means and standard deviations of baseline categorical boundaries, for each group on each day.

Figure 3.6

Predicted means and standard deviations of baseline categorical boundaries, for each group on each day.



As the plotted means (see Figure 3.6) demonstrate a curvilinear effect of day, a linear mixed-effects model including day as a continuous variable with quadratic and cubic polynomial terms and an autocorrelation structure included (corCAR1; Pinheiro et al., 2020), was also conducted. The findings were consistent with the model and pairwise comparisons reported above, suggesting that statistical outcomes are similar using both strategies and that the findings are reliable.

Linear Mixed-Effects Model of Perceptual Training.

$$y_i = \beta_0 + \beta_1 x_1 * \beta_2 x_2 * \beta_3 x_3 + \mathrm{u}_{\mathrm{j}1} + \epsilon_{ij1}$$

y_i = categorical boundary, x_1 = day (1, 2, 3, 4), x_2 = condition (intervention or control), x_3 = training (pre or post) u_{j1} = random intercept of the participant (participant ID) and ϵ_{ij1} = residual error.

Similar to the baseline model, day (1, 2, 3, 4), condition (intervention and controls), and in this case, training (pre-training/baseline and post-training/test boundary), were permitted as categorical variables.

The model revealed that there was a significant Type III main effect of day ($F(3,252) = 14.15$, $p < .001$), but no significant main effect of condition ($F(1,36) = 0.59$, $p > .05$) or training ($F(1,252) = 0.18$, $p > .05$). There was a significant two-way interaction for condition X day ($F(3,252) = 6.63$, $p < .001$). No other two-way or three-way interactions were significant (*p*s > .05). The conditional R^2 was .80 showing that the model explained approximately 80% of the variance in the data. A full summary of the model can be found in Table C.5, Appendix C.

Pairwise comparisons indicated that for the intervention group, there was a significant difference between day 1 baseline and day 4 post-training ($p < .001$), where the categorical boundary increased by approximately 4.96 BMI units over the course of the training. For each day of training, there was no significant difference between baseline and post-training categorical boundaries (all *p*s > .05). The pre- vs post-training mean differences were reported earlier for the 2 X 2 ANOVA, where the difference diminished across the course of training but was higher for the intervention group than for the control group. This indicates that despite the post-training categorical boundary increasing on each day, this was not a significant increase in BMI at the $p < .05$ level. Similarly, for the control group, there was a significant difference between day 1 baseline and day 4 post-training ($p < .05$) by 2.26 BMI units. For each day of training, there was no significant difference between baseline and post-training categorical boundaries (all *p*s > .05).

As before, a polynomial model including an autocorrelation structure revealed the same outcomes as reported above, suggesting that statistical outcomes are similar using both strategies and that the findings are reliable.

3.5.4 *Psychometrics*

Descriptive statistics (mean, standard deviation, and range) for the participant's psychometrics and Spearman's correlations between the psychometric measures, for the whole sample and each condition separately, can be found in Appendix C. Given the substantial correlations between many of the psychometric scores, a PCA was used to identify significant latent variable/s in the psychometric data, for the whole sample - this technique has been used in a variety of published research (e.g. Cornelissen et al., 2015; Irvine et al., 2020; Thaler, Geuss et al., 2018). The EDE-Q Global score was omitted from this analysis, as the four subscale scores were used, resulting in a total of nine variables in the PCA. The factor scores from the latent variable 'psych' are used in subsequent analyses. See Appendix C for details of the PCA and factor loadings. The 'psych' scores for each group on each day are presented in Table 3.3. Independent t-tests for each day of measurement (1, 4, 15, and 30) revealed that there were no significant differences between the intervention and control groups 'psych' scores (all *p*s > .05), indicating that both groups had similar levels of psychological concerns.

Table 3.3

Descriptive statistics of the 'psych' scores for each group (intervention and controls) and between-group differences, on each day of testing.

Day	Intervention	Controls	Overall		Int vs Con
	M (SD)	*M* (SD)	*M* (SD)	Range	*p*
1	0.36 (0.69)	0.20 (0.96)	0.28 (0.83)	-2.26 – 2.53	> .05
4	-0.04 (0.97)	-0.22 (1.08)	-0.13 (1.02)	-2.48 – 2.34	> .05
15	0.10 (1.00)	-0.32 (1.10)	-0.12 (1.06)	-2.65 – 2.45	> .05
30	0.10 (1.02)	-0.18 (1.12)	-0.04 (1.07)	-2.55 – 2.46	> .05

Abbreviations. Int = Intervention Group, Con = Control Group

3.5.5 *Linear Mixed-Effects Model of Psychological Concerns*

A linear mixed-effects model predicting 'psych' scores was conducted. Condition and day were included as fixed effects as categorical variables. There were four levels for day (days 1, 4, 15, and 30) and two levels of condition (intervention and control). To determine whether permitting random variation was warranted, an intercept only model was compared to a random intercept only model allowing variation from participants. The model including a random intercept for participants was the best model fit due to decreased AIC/BIC values and a significant reduction in log-likelihood ($p < .001$).

$$y_i = \beta_0 + \beta_1 x_1 * \beta_2 x_2 + \mathrm{u}_{j1} + \epsilon_{ij1}$$

y_i = 'psych', x_1 = day, x_2 = condition, u_{j1} = random intercept of the participant (participant ID) and ϵ_{ij1} = residual error.

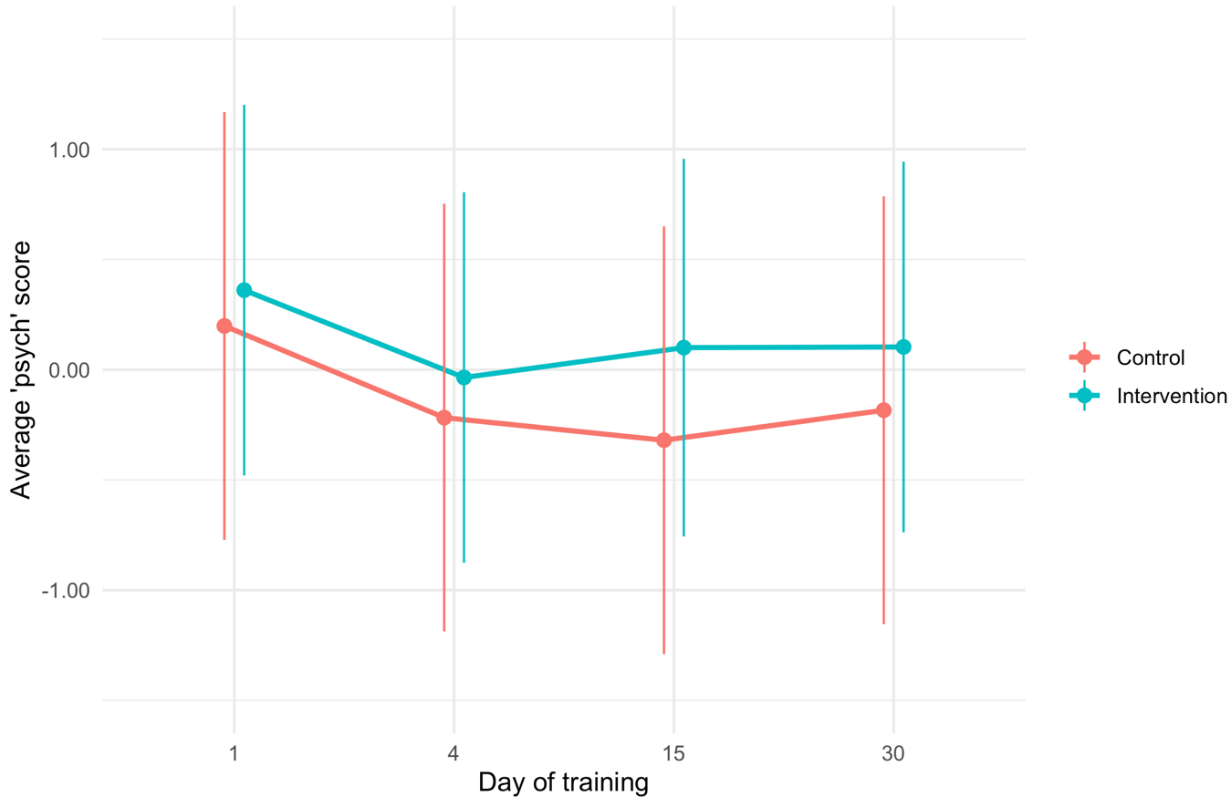
The conditional R^2 for the model was .87, showing that the model explained approximately 87% of the variance in the data. The model revealed that there was a significant

Type III main effect of day ($F(1,107) = 7.50$, $p < .001$), but no significant main effect of condition ($F(1,36) = 0.27$, $p > .05$) or day X condition interaction ($F(1,107) = 1.21$, $p > .05$) on 'psych'. This indicates that 'psych' scores decreased across the duration of the study, irrespective of condition. A full summary of the model can be found in Table C.9, Appendix C.

Pairwise comparisons revealed that there were no significant differences between intervention and control 'psych' scores on each day of testing (all *p*s > .05), suggesting that there were no significant differences in psychological concerns between the groups at baseline, post-training or at the follow-up dates. For the control group, there was a significant decrease in 'psych' at day 4 post-training and at the follow-up sessions (days 15 and 30) compared to day 1 (*p*s < .040). However, for the intervention group, the 'psych' score was only significantly lower at day 4 post-training ($p = .029$) but not at follow-up sessions (*p*s > .05), compared to day 1 baseline. Compared to day 4 (post-training), there were no significant differences between 'psych' scores at each follow-up session (days 15 and 30; *p*s > .05) for either group, this indicates that decreases in post-training psychological concerns were maintained up to day 30. Similarly, there were no significant differences between day 15 and 30 for either group (*p*s > .05), which indicates that the psychological concerns were stable for the two weeks between follow-ups. Figure 3.7 displays the predicted means and standard deviations of 'psych' scores, for each group on each day.

Figure 3.7

The predicted mean and standard deviation of 'psych' score, for each group on each day.



3.5.6 *Interactive 3D Body Size and Shape Estimates*

For conciseness, the focus of this results section is on body size (BMI) from the interactive body estimates. All analyses for body shape (WHR, WBR and BHR) can be found in Appendix C, along with exploratory analyses investigating relationships with actual body measurements.

Perceived Current Body Size and BID. Table 3.4 presents the descriptive statistics of the participant's perceived current body size and the discrepancy between perceived and actual (BID), separately for each condition and each time point.

Table 3.4

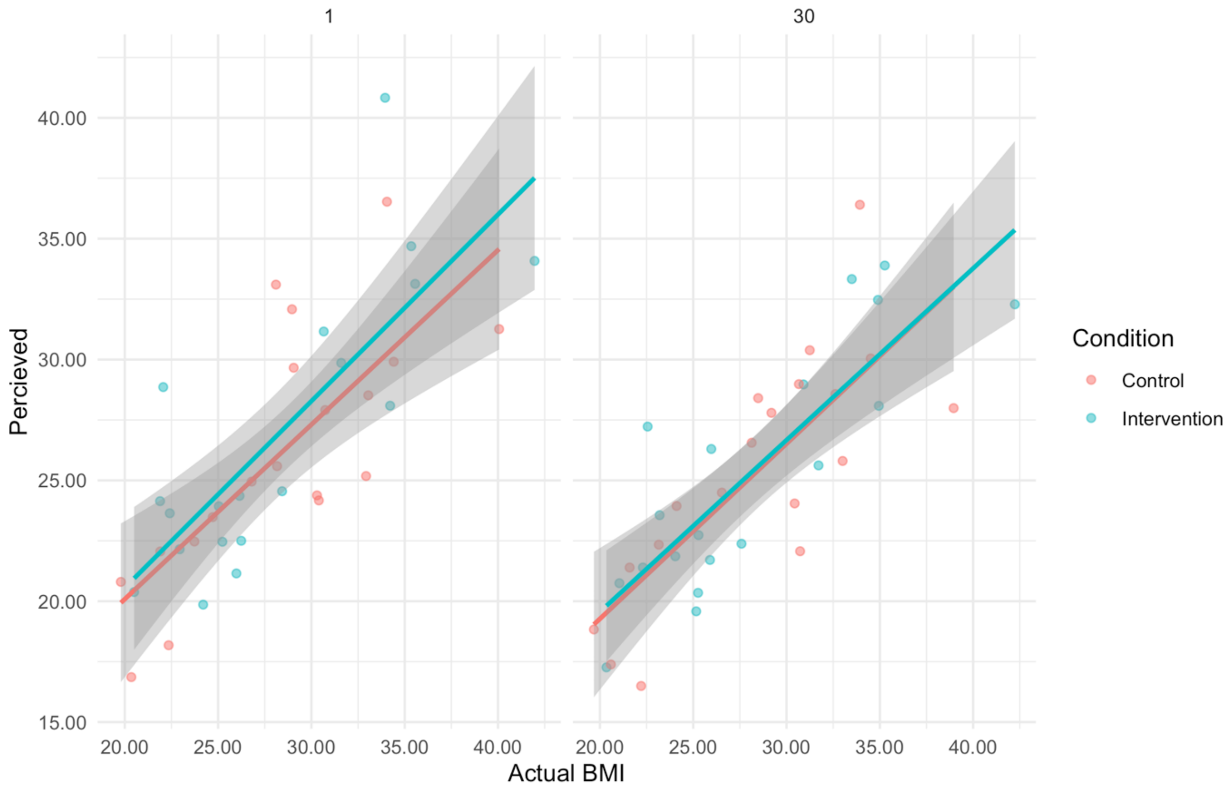
Descriptive statistics (mean and standard deviation) of the participant's perceived current BMI and the discrepancy between perceived and actual BMI (BMI BID), for each condition and day.

Variables	Intervention		Controls	
	Day 1	Day 30	Day 1	Day 30
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)
Perceived BMI	26.83 (5.79)	25.25 (5.08)	26.16 (5.15)	25.36 (4.95)
BMI BID	-1.29 (3.81)	-2.76 (3.28)	-2.25 (3.72)	-3.04 (3.42)

There were significant positive correlations between perceived and actual BMI for both conditions, on each day (all ps < .05, see Appendix C). This suggests that as actual BMI increased as did perceived BMI (see Figure 3.8). The discrepancy between perceived and actual BMI (see Table 3.4) indicates that the women generally underestimated their BMI around 1.29 - 3.04 BMI units, on average. This suggests that the women were fairly accurate at estimating their BMI. A 2 (Day: 1 vs 30) X 2 (Condition: Intervention vs Controls) mixed ANOVA revealed that there were no significant effects of day or condition on perceived BMI (ps > .05). A 2 X 2 mixed ANOVA revealed that there were no significant effects of day or condition on BID (p > .05). This indicates that there were no significant differences in perceived body size or body size estimation accuracy between the first and last session or between the intervention and controls groups.

Figure 3.8

The relationship between perceived and actual BMI at each time point (day 1 and 30), with coloured points and lines denoting the intervention and control groups.



Ideal Body Size/Shape and Perceptual BD. Table 3.5 presents the descriptive statistics of the participant's ideal body size and the discrepancy between perceived and ideal (BD), for each condition and each time point.

Table 3.5

Descriptive statistics (mean and standard deviation) of the participant's ideal BMI and the discrepancy between perceived and ideal BMI (BMI BD), for each condition and day.

Variables	Intervention		Controls	
	Day 1	Day 30	Day 1	Day 30
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)
Ideal BMI	20.27 (2.95)	20.84 (3.39)	20.16 (3.04)	20.16 (3.03)
BMI BD	-6.56 (4.37)	-4.41 (2.64)	-6.00 (4.15)	-5.21 (3.39)

The participants desired an ideal body size at the low end of the normal BMI category - on average 20.36 BMI units (SD = 3.06). This is consistent with evidence suggesting that the most attractive BMI is at the low end of normal (18 - 20 BMI units). The WHR (approximately, 0.75 on average) was also similar to that considered the most attractive (M = 0.70, SD = 0.04) (see Appendix C). There were significant positive correlations between ideal and actual BMI for both conditions, on each day (all ps < .05, see Appendix C). This suggests that as actual BMI increased, as did ideal BMI. The women desired a smaller ideal BMI than their perceived by around 4.41 - 6.56 BMI units, indicative of perceptual body dissatisfaction. A 2 (Day: 1 vs 30) X 2 (Condition: Intervention vs Controls) mixed ANOVA revealed there was no significant effect of day or condition on ideal BMI (ps > .05). This indicates that there were no significant differences in ideal body size between conditions or across the study duration. A 2 X 2 mixed ANOVA revealed that was no significant main effect of day or condition or interaction on BMI BD (ps > .05), suggesting that there were no changes in perceptual BD post-intervention, or between conditions.

3.5.7 *The Relationship Between Categorical Boundary, Psychological Concerns, and Body Estimates*

Spearman's Rank correlations were conducted to determine the relationship between baseline categorical boundary and 'psych' on days 1, 15 and 30. There were no significant correlations on days 1 (r_s = -.20, p > .05), 15 (r_s = -.25, p > .05), or 30 (r_s = -.23, p > .05). Similarly, no significant correlation was found between post-training boundary and 'psych' on day 4 (r_s = -.32, p = .052). There were no significant correlations between categorical boundary and body size estimations, at either time point (day 1 or 30): Perceived current BMI (day 1, r_s = -.09, p > .05; day 30, r_s = -.09, p > .05), ideal BMI (day 1, r_s = .07, p > .05; day 30, r_s = .01, p > .05), BMI BID (day 1, r_s = .09, p > .05; day 30, r_s = .13, p > .05), or BMI BD (day 1, r_s = .17, p > .05; day 30, r_s = .16, p > .05). This suggests that categorical perceptions of thinness were not associated with participant's self-specific perceptions of body size or their psychological concerns.

Summary of Results

In conclusion, the findings from Study 1 demonstrate that the thin/fat categorical boundary was significantly higher after receiving inflationary feedback (intervention condition) which aimed to manipulate perceptions. For this group, on average, the boundary increased by approximately 5 BMI units, from the low end of the normal BMI category (20.63 BMI units) to the border of the overweight BMI category (25.38 BMI units), and this was maintained at both the two-week and 30-day follow-ups. For those receiving feedback to maintain perceptions (control condition), there was an increase in the thin/fat categorical boundary by approximately 2 BMI units (staying within 21.24 and 22.94 BMI units on average throughout the study duration, which is in the normal BMI category), and this was maintained at both the 2-week and 30-day follow ups. Both groups demonstrated a decrease in psychological concerns across the 30 days, indicating that there were no intervention specific effects on psychological outcomes, as predicted based on previous findings. There were no significant changes in perceived or ideal body size between day 1 and 30 for either group and no differences in body size distortion or perceptual dissatisfaction, indicating that perceptual body image was stable and there were no intervention specific effects. These findings suggest that the intervention can successfully shift general perceptions of thinness and fatness using CG avatars, but this does not seem to alter individual's self-specific perceptual body image or psychological concerns in women with heightened body concerns.

Study 2: Investigating the Relationship Between Attitudinal and Perceptual Body Image in Women with High Vs Low/Mild Body Concerns, Using an Interactive 3D Software and Categorical Body Size Perception Task

Perceptual and attitudinal components of body image are often considered distinct yet interrelated. Some researchers have argued that the body norms and ideals of women with high body dissatisfaction may be more resistant to changes (Glauert et al., 2009; Wedell et al., 2005), for example, using the CBM in Study 1. In Study 1 it was found that the CBM protocol could successfully manipulate categorical perceptions of body size (thin/fat boundary) in a sample of females with heightened body concerns, but this was not related to perceptual body image or psychological concerns. Therefore, to further understand the relationship between perceptual and attitudinal body image, we compared baseline measurements from those identified as having high body concerns from Study 1 to those identified as having low/mild body concerns (recruited specifically for this study). The relationships between categorical perceptions of body size, attitudes/psychological concerns and one's own body size/shape were explored.

3.6 Method

Ethical approval was gained from the University of Lincoln Research Ethics Committee (Project code: 0824).

3.6.1 *Aims*

The main aim of this study was to explore the relationship between two components of body image in two groups of women differing in body, weight, and shape concerns, i) the perceptual component – measured looking at perceptions of their own perceived and ideal body/size shape using an interactive 3D software, and categorical perceptions of what is a ‘thin’ and ‘fat’ body size, and ii) the attitudinal component – measured using self-report questionnaires about body image, disordered eating psychopathology, self-esteem, depression, and internalisation of body ideals.

3.6.2 *Participants*

Thirty women identified as having low/mild body concerns (henceforth referred to as the ‘low concerns group’) using the BSQ 16B took part in this study. Prior to participation in the study, potential participants were screened online using a Qualtrics form to determine eligibility (females [cis-gender/as assigned at birth], aged 18+, with no history/current diagnosis of an eating disorder). Only those with BSQ scores 51 or below were contacted to take part. A total of 64 people completed the pre-screening, of which 41 were contacted and 30 visited the lab to take part. Participants were recruited using advertisements around the University and city centre, social media posts, and word of mouth. Undergraduate psychology students received course credits for participation.

For the high body concerns group, data from the 38 females that took part in Study 1 (scoring 60 or above in the BSQ), were used (see Section 3.2.2 for details of recruitment).

Overall, the final sample consisted of 68 females that were predominantly Caucasian (88.24%), with 7.35% Asian (Arab, Chinese, Nepalese, and Pakistani), and 4.41% mixed ethnicity. Table 3.6 presents participant characteristics for the whole sample, for both the low and high body concerns groups separately, and statistical differences between groups determined using independent samples t-tests.

Table 3.6

Descriptive statistics of participant's age, BMI, and BSQ pre-screen scores and statistical differences between groups.

Variable	High Concerns (n = 38)	Low Concerns (n = 30)	Overall		High vs Low
	M (SD)	*M* (SD)	*M* (SD)	Range	*p*
Age	23.21 (7.94)	24.40 (7.38)	23.74 (7.66)	18.00 - 48.00	> .05
BMI	28.27 (5.56)	22.60 (3.63)	25.77 (5.55)	16.50 - 41.96	< .001
BSQ	71.32 (8.33)	36.57 (9.56)	55.99 (19.49)	20.00 - 96.00	< .001

3.6.3 *Materials*

Interactive 3D Body Size and Shape Estimates

As in Study 1, participants with low body concerns were asked to create their perceived current and ideal body size/shape using the Daz3D Studio interface, using the same randomisation procedure to counteract anchoring and procedural effects. The 3D body estimates for the high body concerns group were taken from Day 1 of Study 1.

Psychometrics

A series of validated questionnaires were used to assess attitudinal body image, including eating disorder psychopathology, body concerns, internalisation of body ideals, self-esteem, and depression (see Section 2.2, Chapter 2). For the whole sample, Cronbach's alpha for the BSQ, EDE-Q, RSES, BDI, SATAQ-4 Thin Ideal Internalisation, and SATAQ-4 Athletic Ideal Internalisation, was .96, .94, .91, .91, .79, and .91, respectively.

Categorical Boundary

The categorical boundary was calculated using the baseline sequence of the CBM task used in Study 1, using the same procedure and stimuli (see Section 3.2.3). Categorical boundary scores for the high body concerns group were taken from the baseline sequence on Day 1 of Study 1.

Body Measurements

Estimates of body composition and BMI were taken using the Tanita BIA scale, standing height using a stadiometer, and circumference measurements using a tape measure (see Section 2.1, Chapter 2).

3.7 Procedure

The procedure was matched in task order to Study 1 to allow comparisons. Firstly, after providing informed consent, participants completed the interactive 3D body estimates using Daz 3D Studio. They were first shown an example body and each of the sliders were explained and manipulated by the researcher to facilitate familiarity. Afterwards, participants created their body estimations (perceived current and ideal body size/shape) by instructing the researcher on which sliders to manipulate and by how much. There was no time limit and the participants could manipulate the body as much as they wanted. Secondly, demographic information (age and ethnicity) and psychometric measures were completed using a Qualtrics form. Next, the categorical boundary task was completed on PsychoPy. These tasks were completed on a 21.5" flat-panel LCD screen with a resolution of 1920 by 1080 pixels in a university lab. Lastly, each participant's body measurements were taken and they were debriefed.

3.8 Data Analysis

Analyses were conducted using 'R Studio' (R Version 4.0.2).

The categorical boundaries were converted to the corresponding stimulus BMI in the same way as in Study 1. For the interactive 3D body size/shape estimations, as in Study 1, circumference measurements in cms (bust, waist, and low hip) were taken from each Daz 3D body creation using the 'measure metrics' tool, after scaling to match the participant's height. As each body estimation (perceived current and ideal) was created twice using two different starter bodies (one underweight and one obese), the average of the measurements was used for each body estimation for all analyses.

Additionally, for this study, a PCA was used to determine latent variable/s in the Daz 3D body estimations. Each of the body estimations were exported as 3D object files, with the clothing and hair excluded to minimise the influence of these extraneous features. This enabled further analysis of perceived/ideal body size/shape beyond circumference measurements, ratios, and estimated BMI, to capture variance in 3D body shape which may have been missed. The average of the two body shapes for both perceived current and ideal for each participant was used in the PCA. The factor score/s for perceived current and ideal were then used for analyses.

For variables where the assumption of normality was violated, determined using Saphiro-Wilk tests (*p*s < .05) non-parametric alternatives of statistical tests were used. The variables that were not normally distributed included the participants' age, actual body size/shape (BMI/WHR/WBR/BHR), all psychometric measures (except SATAQ-4 subscales), perceived BMI and BHR, ideal WBR and BHR, perceptual BD (BMI/WBR/BHR), BID BMI, and categorical boundary.

3.9 Results

3.9.1 *Participant Characteristics*

Table 3.7 presents participant characteristics and between-group significance values. When looking at the sample distribution according to BMI category, 4.41% (n = 3) were underweight, 47.06% (n = 32) were normal weight, 23.53% (n = 16) were overweight, and 25.00% (n = 17) were obese. There were no statistically significant differences between the age, height, and BHR between the two groups, determined using Wilcoxon Signed-Rank Tests (*p*s > .05). There were statistically significant differences between the groups BMI, WHR, and WBR (all *p*s > .05), where the high concerns group had higher BMIs, WHR and WBR, on average.

Table 3.7

A summary of the participant's characteristics.

	High Concerns	Low Concerns	Overall		High vs low
Participant Characteristic	*M* (SD)	*M* (SD)	*M* (SD)	Range	*p*
Age	23.21 (7.94)	24.40 (7.38)	23.74 (7.66)	18.00 – 48.00	> .05
Height	165.21 (5.84)	167.10 (4.88)	166.04 (5.48)	152.00 – 178.00	> .05

	High Concerns	Low Concerns	Overall		High vs low
Participant Characteristic	*M* (SD)	*M* (SD)	*M* (SD)	Range	*p*
BMI	28.27 (5.56)	22.60 (3.63)	25.77 (5.55)	16.50 - 41.96	< .001
WHR	0.82 (0.06)	0.77 (0.06)	0.80 (0.07)	0.64 – 0.98	.001
WBR	0.90 (0.07)	0.84 (0.06)	0.87 (0.07)	0.71 – 1.16	< .001
BHR	0.91 (0.05)	0.92 (0.06)	0.92 (0.05)	0.83 – 1.14	> .05

3.9.2 *Psychometric Measures*

Descriptive statistics for psychometric data and statistical differences between each group is presented in Appendix D. As in Study 1, a PCA was conducted due to multi-collinearity and the factor scores for the latent factor (‘psych’) is used in subsequent analyses (see Appendix D). ‘Psych’ represents a combination of attitudes related to body image and feelings towards the self. Higher scores on this latent factor indicate increased body/weight/shape concerns, disordered eating symptomology, depressive symptoms, internalisation of thin and athletic body ideals, and lower self-esteem. An independent samples t-test revealed that there were significant group differences for ‘psych’ scores ($t(60.44) = -6.94$, $p < .001$), where the high concerns group scored significantly higher ($M = 0.58$, $SD = 0.74$) than the low concerns group ($M = -0.73$, $SD = 0.79$).

3.9.3 *Interactive 3D Body Size/Shape Estimates (Measurements)*

Perceived Current Body Size/Shape and BID. Descriptive statistics of perceived current body size/shape and the significance values denoting between-group differences are presented in Table 3.8.

Table 3.8

Descriptive statistics of the participant's perceived current body size/shape variables and significance values for between-group differences.

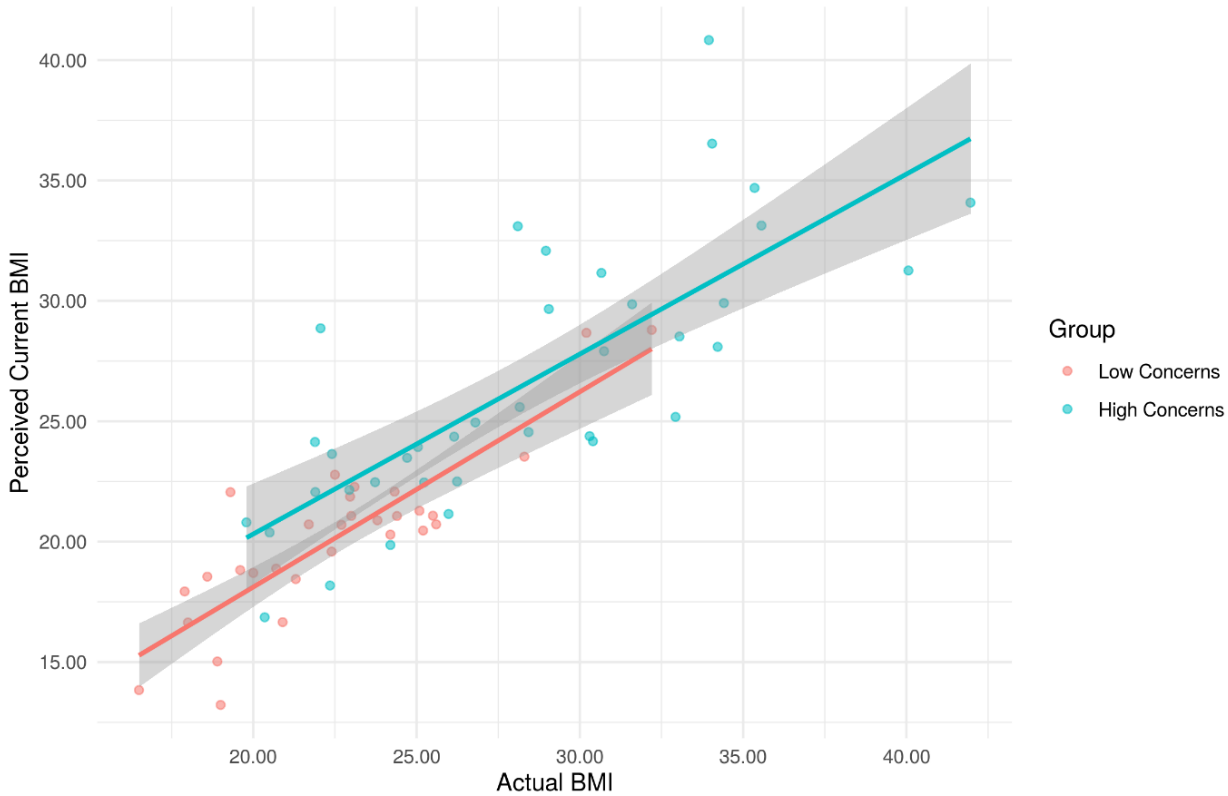
Variables	High Concerns	Low Concerns	Overall		High vs low
	M (SD)	*M* (SD)	*M* (SD)	Range	*p*
BMI	26.50 (5.42)	20.22 (3.43)	23.73 (5.58)	13.22 – 40.83	< .001
WHR	0.77 (0.04)	0.74 (0.03)	0.75 (0.04)	0.65 – 0.86	< .001
WBR	0.85 (0.07)	0.78 (0.05)	0.82 (0.07)	0.68 – 1.01	< .001
BHR	0.90 (0.05)	0.94 (0.03)	0.92 (0.05)	0.77 – 1.01	< .001

The perceived current body size/shape variables were significantly correlated with actual BMI in the whole sample: BMI ($r_s = .86$, $p < .001$), WHR ($r_s = .55$, $p < .001$), WBR ($r_s = .72$, $p < .001$), and BHR ($r_s = -.62$, $p < .001$), which all remained significant when considering the low concerns group (all *p*s ≤ .012) and the high concerns group (all *ps* ≤ .008) separately. This shows that increases in BMI was associated with increases in perceived BMI, WHR, and WBR but decreases in perceived BHR. Further exploratory analyses investigating the relationships between actual and perceived body size/shape are presented in Appendix D. Perceived current body size/shape was significantly correlated with 'psych' in the whole sample for BMI ($r_s = .42$, $p < .001$), WBR ($r = .32$, $p = .009$) and BHR ($r_s = -.35$, $p = .004$), but not WHR ($r = .20$, $p > .05$). This indicates that as psychological concerns increased as did perceived BMI and WBR, whereas perceived BHR decreased. Only the relationship between perceived BMI and 'psych' remained significant when controlling for actual BMI ($r_s = .26$, $p = .033$), suggesting that increased perceived body size was associated with increased psychological concerns. When considering the groups separately, these correlations were no longer significant (all *p*s > .05).

A multiple linear regression was used to predict perceived current BMI from ‘psych’, group (high vs low), and actual BMI ($F(3, 64) = 61.65$, $p < .001$, $R^2 = .73$). There was a significant main effect of BMI ($B = 0.76$, $t = 10.30$, $p < .001$). There were no significant effects of ‘psych’ or group. This indicates that for every increase of the women’s BMI there was an increase of approximately 0.76 BMI units for their perceived BMI, such that those with higher BMIs perceived themselves as a higher BMI (see Figure 3.9), irrespective of body and psychological concerns. Although, it should be noted that perceived current BMI is not normally distributed and despite a strong positive correlation with actual BMI (determined using Spearman’s Rank correlations), this result should be interpreted with caution.

Figure 3.9

The relationship between perceived current and actual BMI, with coloured points and lines denoting the relationship for each group (low and high concerns).



Next, the discrepancy between perceived and actual body size/shape (BID) was explored. One sample significance tests (comparing BID size/shape variables to 0, where 0 represents no difference between perceived and actual body size/shape) revealed that both high and low concerns groups significantly underestimated their BMI, WHR and WBR, on average (all *p*s < .05). Only the low concerns group significantly underestimated their BHR ($t(29) = -3.19$, $p = .003$), whereas, the high concerns group displayed no significant BID for their BHR ($t(37) = 0.90$, $p > .05$). There were no significant differences between high and low concerns groups for BMI, WHR, and WBR BID, indicating that irrespective of body concerns, the females tended to underestimate their overall body size and waist width relative to hips and bust. There was a significant group difference for BHR BID, where the low concerns significantly underestimated compared to the high concerns group who had an accurate representation of their BHR. Descriptive statistics and significance values of between-group differences are reported in Table 3.9.

Table 3.9

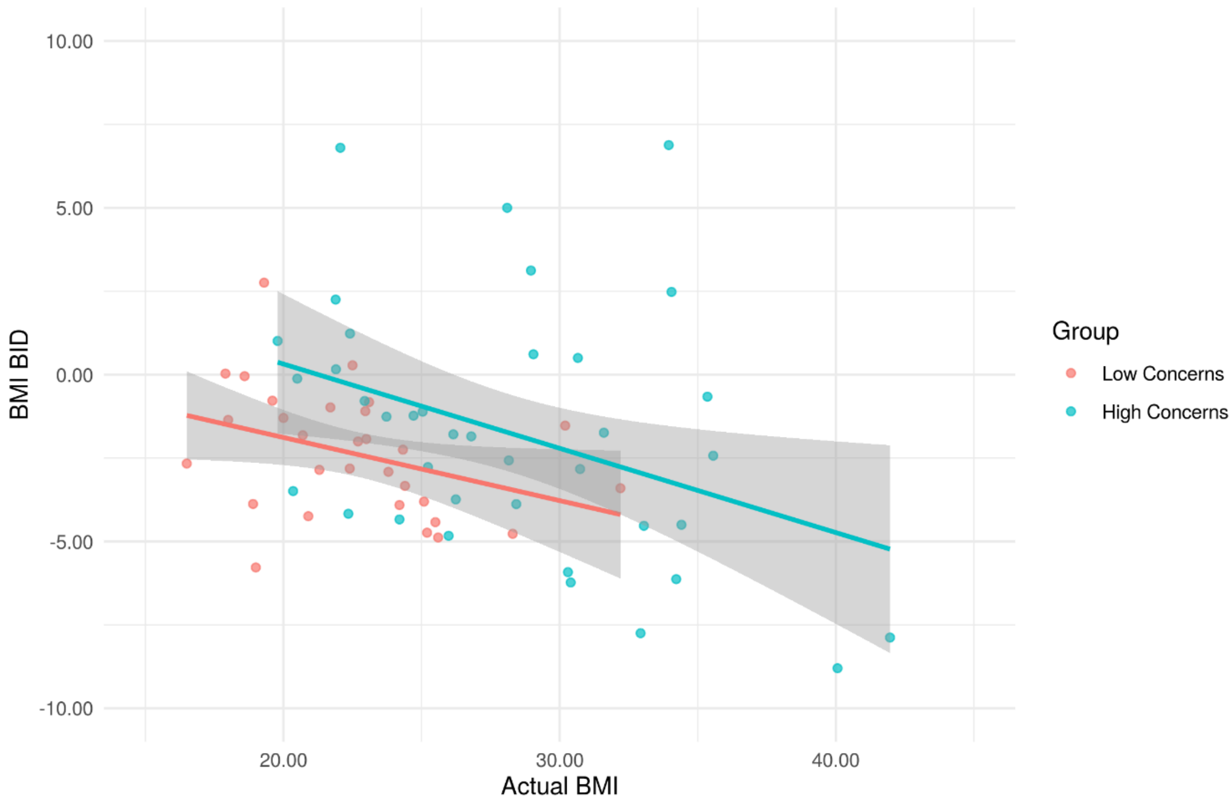
Descriptive statistics of the discrepancy between perceived current and actual body size/shape, for the whole sample and each group separately, and significance values of between-group differences.

Variables	High Concerns	Low Concerns	Overall		High vs low
	M (SD)	*M* (SD)	*M* (SD)	Range	*p*
BMI	-1.77 (3.75)	-2.38 (1.88)	-2.04 (3.06)	-8.80 – 6.88	> .05
WHR	-0.05 (0.07)	-0.04 (0.05)	-0.05 (0.06)	-0.24 – 0.11	> .05
WBR	-0.05 (0.08)	-0.05 (0.04)	-0.05 (0.06)	-0.25 – 0.08	> .05
BHR	0.01 (0.06)	-0.03 (0.06)	-0.01 (0.06)	-0.23 – 0.12	.007

For the whole sample, there were significant negative correlations between actual BMI and BMI BID (r_s = -.29, p = .015), WHR BID (r_s = -.35, p = .004), and BHR BID (r_s = .49, p < .001). For the high concerns group, there were significant negative correlations between actual BMI and BMI BID (r_s = -.36, p = .025) and BHR BID (r_s = .52, p = .003). For the low concerns group, there were significant negative correlations between actual BMI and BMI BID and (r_s = -.46, p = .012) and WHR BID (r_s = -.39, p = .032). Figure 3.10 demonstrates the relationship between actual BMI and BMI BID. This demonstrates that as actual BMI increased, BID decreased and became more negative indicative of underestimation of BMI, supporting predictions by contraction bias (overestimation of lower BMI bodies and underestimation of higher BMI bodies).

Figure 3.10

The relationship between actual BMI and the discrepancy between perceived current and actual BMI (BMI BID) with coloured points and lines denoting the relationship for each group.



There were no significant correlations between BMI BID, WHR BID, WBR BID and 'psych' (*ps* > .05), indicating that under-/over-estimation of these body size/shape variables was not significantly related to psychological concerns. There was a significant positive correlation between BHR BID and 'psych' (r = .26, p = .029), indicating that overestimation of BHR was associated with increased concerns. This was no longer significant when controlling for actual BMI (r_s = .15, p > .05). There were no significant correlations between BID variables and 'psych' when considering high and low concerns groups separately (all *p*s > .05). This indicates that body size/shape estimation accuracy, or BID, is significantly related to the individuals own BMI but not psychological concerns.

A multiple linear regression was used to predict BMI BID from ‘psych’, group (high vs low) and actual BMI ($F(3, 64) = 3.66$, $p = .017$, $R^2 = .11$). There was a significant main effect of BMI ($B = -0.24$, $t = -3.19$, $p = .002$). There were no significant effects of ‘psych’ or group. This indicates that for every increase of the women’s BMI there was a decrease of approximately 0.24 BMI units for BMI BID, such that those with higher BMIs underestimated their body size (see Figure 3.10), irrespective of body and psychological concerns. Although, it should be noted that BMI BID is not normally distributed and despite the significant relationship with actual BMI (determined using Spearman’s Rank correlations), this result should be interpreted with caution.

Ideal Body Size/Shape and Perceptual BD. The largest ideal body size had an estimated BMI of 25.78 which is just over the boundary of overweight, despite actual and perceived BMI reaching the obese class III category (BMI > 40). For both groups, the average ideal body size was at the low end of the normal BMI range (18.71 for low concerns and 20.22 for high concerns) and the WHR was approximately 0.70, in line with previous findings regarding the most attractive BMI and WHR (18-20 BMI units and 0.70 WHR). There were significant differences between the groups ideal BMI and BHR, where the high concerns group had a significantly higher ideal BMI and lower BHR (a desire for a more ‘pear-shaped figure’ - larger hips/buttocks relative to the breasts). Table 3.10 presents descriptive statistics of ideal body estimates and significance values of between-group differences.

Table 3.10

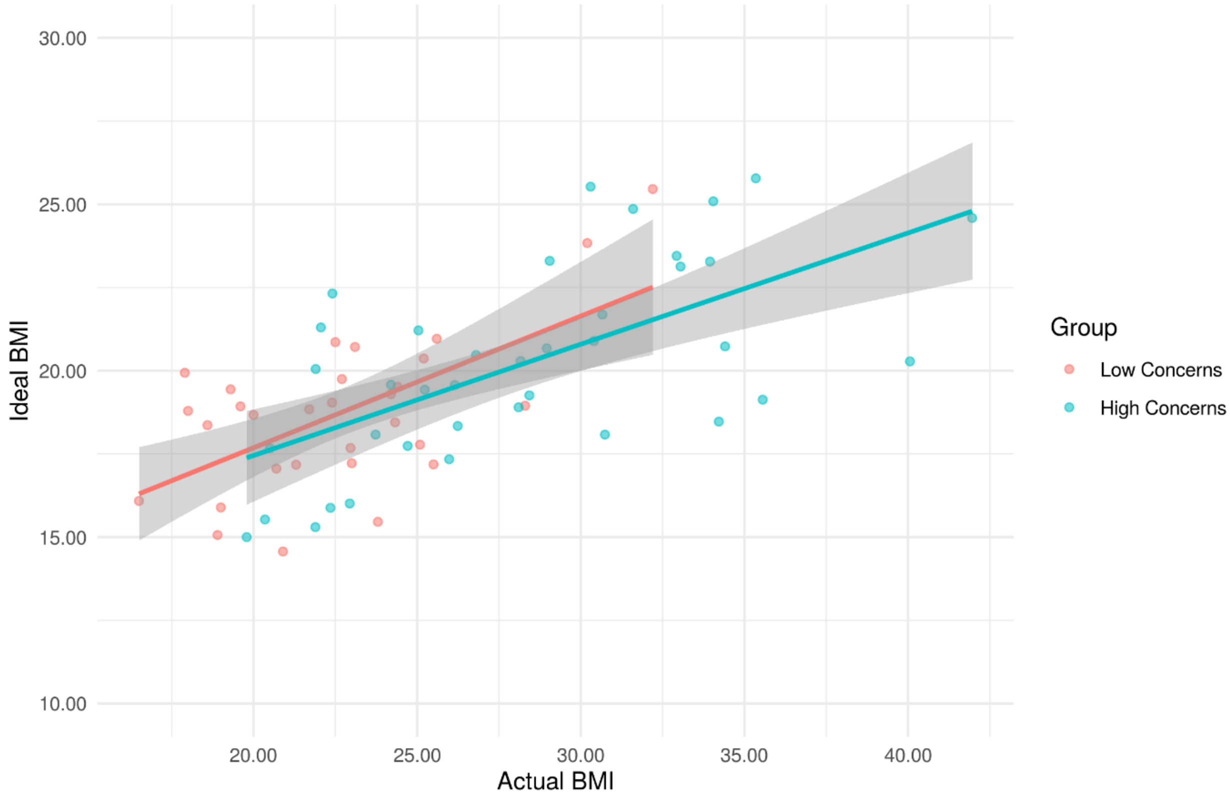
Descriptive statistics of ideal body size/shape variables for the whole sample and each group separately, and significance values denoting differences between groups.

Variables	High Concerns	Low Concerns	Overall		High vs low
	M (SD)	*M* (SD)	*M* (SD)	Range	*p*
BMI	20.22 (2.95)	18.71 (2.35)	19.55 (2.79)	14.57 – 25.78	.022
WHR	0.70 (0.04)	0.71 (0.04)	0.70 (0.04)	0.60 – 0.78	> .05
WBR	0.75 (0.04)	0.74 (0.04)	0.74 (0.04)	0.65 – 0.83	> .05
BHR	0.93 (0.03)	0.96 (0.04)	0.95 (0.03)	0.86 – 1.07	< .001

There were significant correlations between the participants actual BMI and their ideal BMI ($r_s = .61$, $p < .001$), WBR ($r_s = .52$, $p < .001$), and BHR ($r_s = -.49$, $p < .001$). This suggests increases in the participant's actual body size were associated with increases in ideal body size and ideal WBR, and decreases in ideal BHR. The positive relationship between actual and ideal BMI is presented in Figure 3.11, showing that those with higher BMIs tend to desire a body which is higher in BMI. For the high concerns group, actual BMI was significantly positively correlated with ideal BMI ($r_s = .61$, $p < .001$) and ideal WBR ($r_s = .45$, $p = .004$). For the low concerns group, actual BMI was significantly positively correlated with ideal BMI ($r_s = .44$, $p = .016$), ideal WHR ($r_s = .44$, $p = .016$), and ideal WBR ($r_s = .53$, $p = .003$). The relationship between actual BMI and ideal BHR was no longer significant when considering the groups separately (high concerns, $r_s = -.28$, $p > .05$; low concerns, $r_s = -.27$ $p > .05$).

Figure 3.11

The relationship between actual and ideal BMI with coloured points and lines denoting the relationship for each group.



There were no significant correlations between 'psych' and the ideal body size/shape variables for the whole sample, determined using Spearman's Rank correlations (all *ps* > .05). For the high concerns group, there were significant correlations between 'psych' and ideal WHR (r = -.37, p = .023) and ideal WBR (r_s = -.34, p = .037), indicating that an increase in psychological concerns (for those with already heightened body concerns) was associated with a smaller WHR and WBR (smaller waist relative to hips and bust i.e. a more 'hourglass' shapes figure). When controlling for actual BMI, the relationship between 'psych' and ideal WBR (r_s = -.35, p = .035) remained significant, whereas it did not for ideal WHR. For those with low concerns, there were no significant correlations between ideal body size/shape and 'psych' (*ps* >

.05). This indicates that for women with heightened body concerns, psychological concerns modulate one's ideal body size, whereas this is not the case for women with low body concerns.

A multiple linear regression was used to predict ideal body BMI from 'psych', group (high vs low), and actual BMI ($F(3, 64) = 18.07$, $p < .001$, $R^2 = .43$). There was a significant main effect of BMI ($B = 0.35$, $t = 6.48$, $p < .001$). There was no significant effect of 'psych' or group. This indicates that for every increase of the women's BMI there was an increase of approximately 0.35 BMI units for their ideal BMI, such that those with higher BMIs desired a higher BMI ideal (see Figure 3.11), irrespective of body and psychological concerns.

Next, the discrepancy between perceived and ideal body size/shape (BD) was explored. One sample significance tests indicated that perceptual BD values (the difference between perceived and ideal body size/shape) for BMI, WHR, WBR, and BHR were all significantly different to 0 (where 0 indicates no difference between perceived and ideal body size/shape) (all ps < .05). Both groups, on average, desired an ideal BMI that was lower than their perceived current BMI. Only eight (11.76%) of the 68 participants desired an ideal body size (BMI) larger than their perceived, of which only one was in the high concerns group. Both groups, on average, also desired a WHR and WBR that were smaller/lower than their perceived. A lower WBR indicates a desire for a larger bust and smaller waist and a lower WHR indicates a desire for a smaller waist relative to hips, i.e. a curvaceous, 'hourglass' figure. Both groups desired a higher BHR than their perceived, indicating a desire for a fuller upper body (larger bust relative to hips). Figures 3.12 and 3.13 display visualisations of the average perceived current and ideal body shapes (created by averaging the exported 3D objects from each participant's Daz body creations, which were subsequently used in a PCA; see Section 3.8 for more details and Section 3.9.4 for the results) for both low and high concerns groups, respectively. The 3D objects representing participants perceived current and ideal body shape were used for visualisation as the Daz sliders are not linear, meaning that it would not be possible to recreate the average body shape using Daz and whilst the measurements taken from the bodies give us an overall idea of size/shape, they do not fully capture the body size/shape/composition of the participant's estimates as the visualising and analysing the exported 3D shapes does.

There were between-group differences for BMI, WHR, and WBR BD (see Table 3.11), where the high concerns group displayed greater BD than those with low concerns. This was negative indicating that there was a desire for a decreased BMI, WHR and WBR, indicative of a desire for a smaller overall body size and a more 'hourglass' figure.

Table 3.11

Descriptive statistics of the discrepancy between perceived and ideal body size/shape for the whole sample and each group separately, and significance values denoting differences between high and low concern groups.

Variables	High Concerns	Low Concerns	Overall		High vs low
	M (SD)	*M* (SD)	*M* (SD)	Range	*p*
BMI	-6.28 (4.21)	-1.51 (2.20)	-4.18 (4.20)	-17.55 – 2.67	< .001
WHR	-0.07 (0.05)	-0.03 (0.03)	-0.05 (0.05)	-0.21 – 0.02	< .001
WBR	-0.11 (0.06)	-0.05 (0.04)	-0.08 (0.06)	-0.24 – 0.03	< .001
BHR	0.03 (0.04)	0.02 (0.04)	0.03 (0.04)	-0.06 – 0.20	> .05

Figure 3.12

The top row shows the perceived current body size/shape and the bottom row shows the ideal body size/shape of the low concerns group, using the average shape from the PCA analysis.

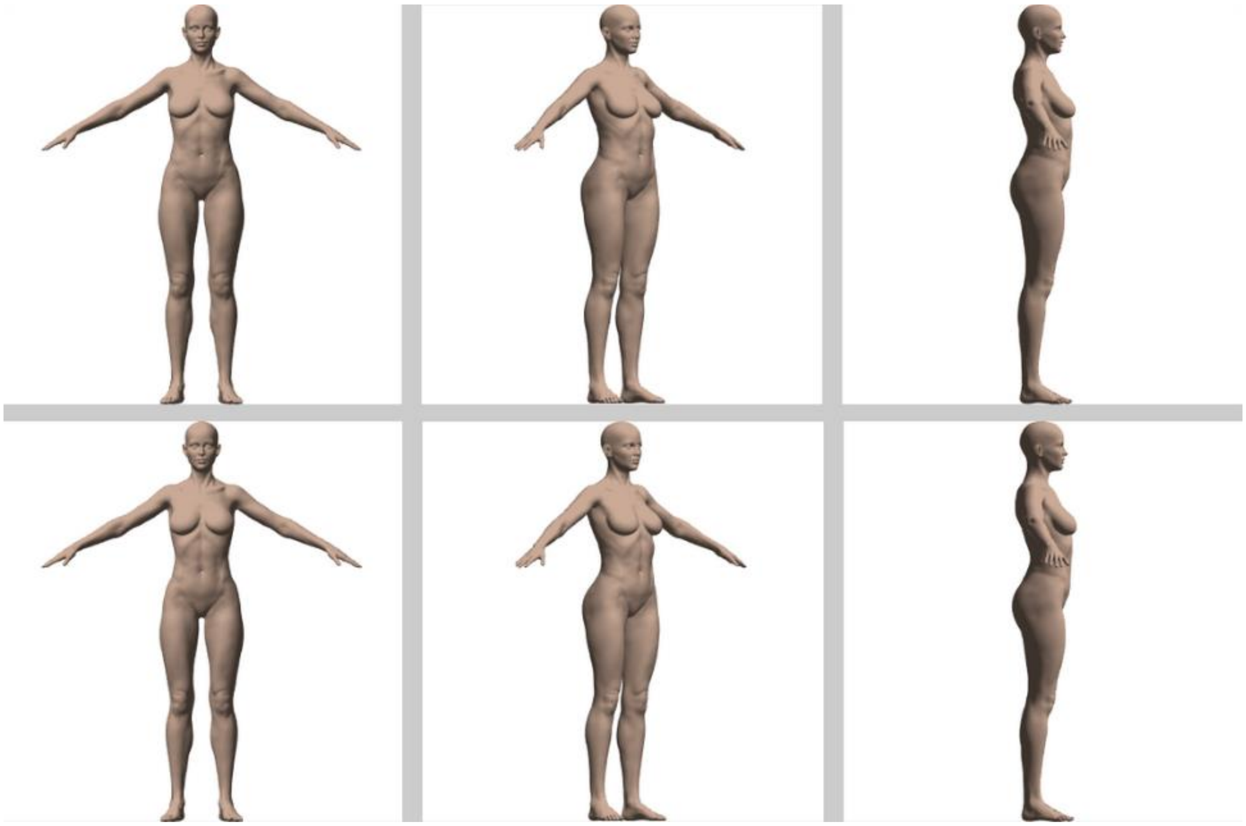
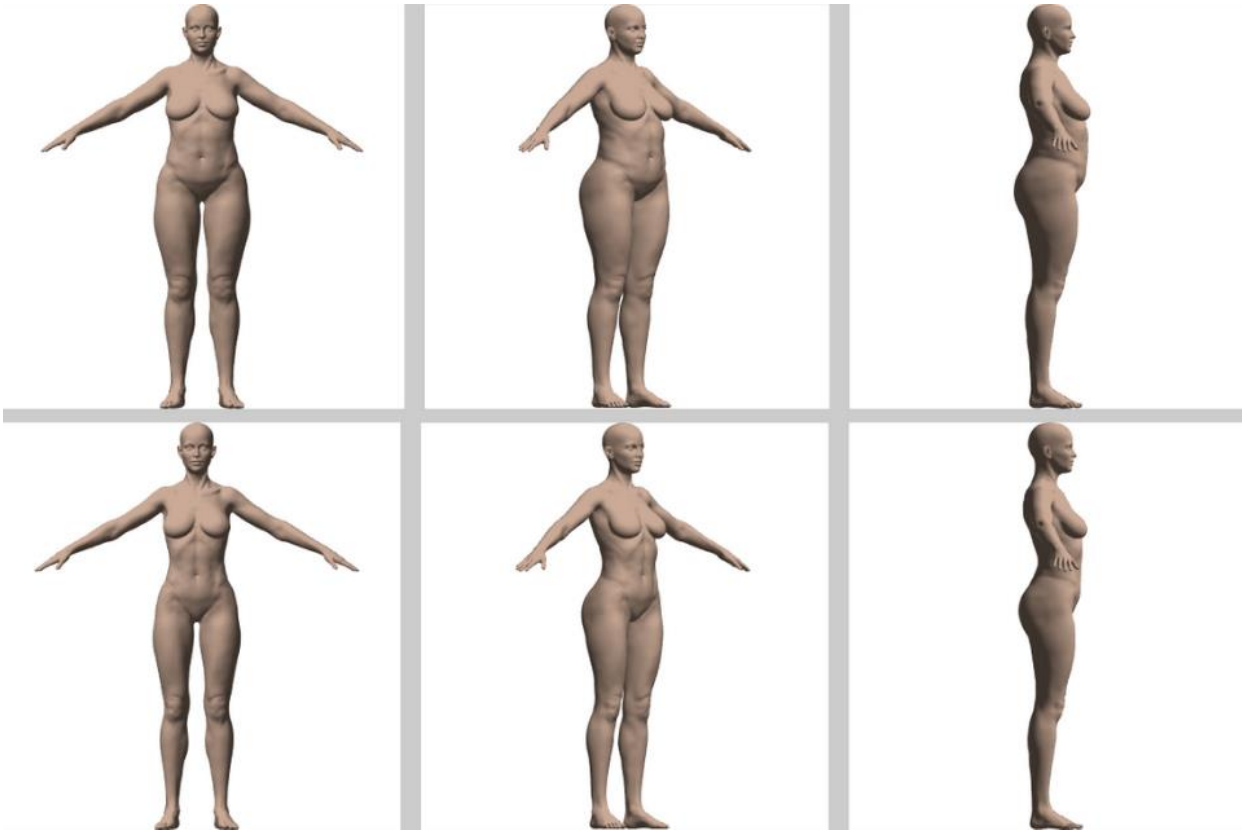


Figure 3.13

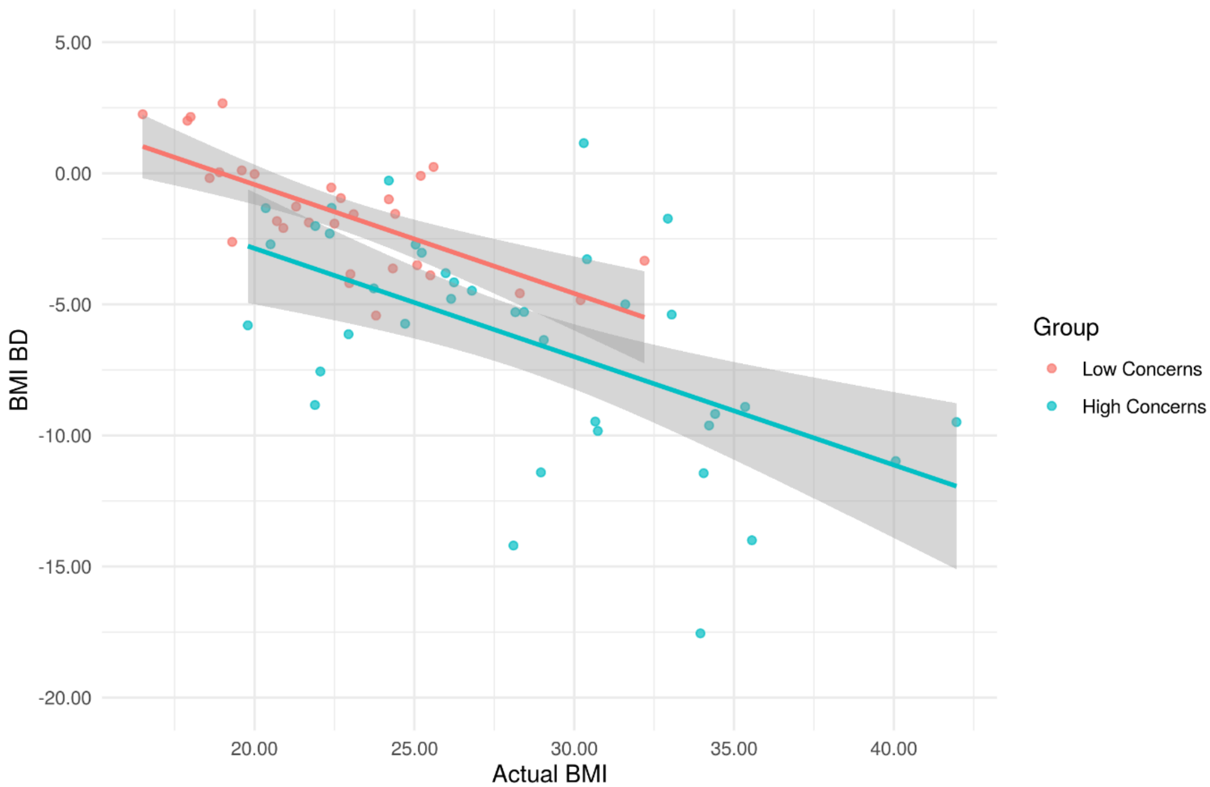
The top row shows the perceived current body size/shape and the bottom row shows the ideal body size/shape of the high concerns group, using the average shape from the PCA analysis.



There were significant correlations between the individuals actual BMI and BMI BD (r_s = -.67, $p < .001$), WHR BD (r_s = -.34, p = .005), WBR BD (r_s = -.44, $p < .001$), and BHR BD (r_s = .31, p = .010), for the whole sample. For the high concerns group, the relationships between BMI BD (r_s = -.56, $p < .001$), WBR BD (r_s = -.38, p = .014) and BHR BD (r_s = .36, p = .025) remained significant. For the low concerns group, only the relationship between actual BMI and BMI BD remained significant (r_s = -.63, $p < .001$). This indicates that, as BMI increased there was a decrease in the discrepancy between perceived and ideal BMI for both groups. As demonstrated in Figure 3.14, BMI BD became increasingly negative as actual BMI increased, indicating that the persons ideal BMI became increasingly smaller than their perceived current BMI, indicative of greater body size dissatisfaction.

Figure 3.14

The relationship between actual BMI and the discrepancy between perceived current and ideal BMI (BMI BD), with coloured points and lines denoting the relationship for each group.

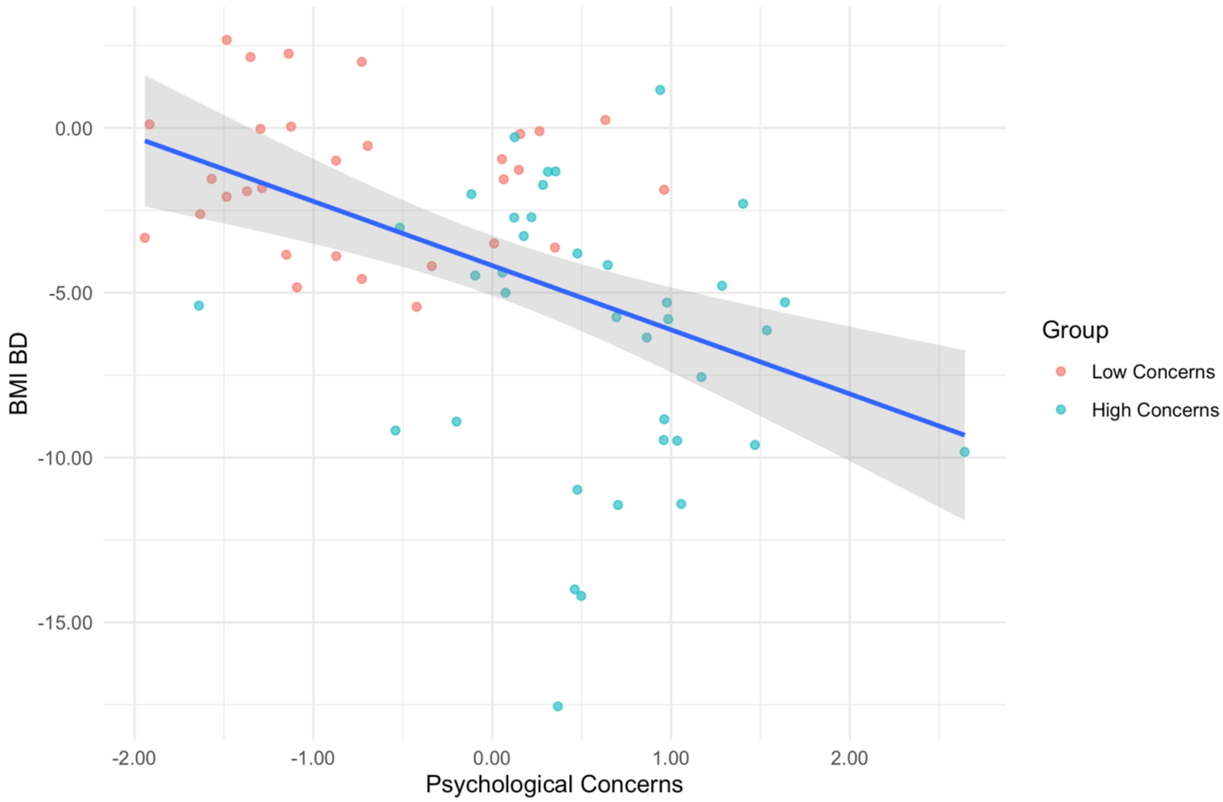


There were significant negative correlations between ‘psych’ and BMI BD (r_s = -.50, p < .001), WHR BD (r_s = -.29, p = .017), and WBR BD (r_s = -.39, p = .001), for the whole sample. There was no significant relationship between ‘psych’ and BHR BD (r_s = .17, p > .05). When controlling for actual BMI, the relationships between ‘psych’ and BMI BD (r_s = -.39, p = .001) and WBR BD (r_s = -.29, p = .019) remained significant. This indicates that increases in psychological concerns were associated with larger negative discrepancies between perceived current and ideal BMI, such that those with higher concerns had an ideal body size smaller than their perceived body size (see Figure 3.15). This is similar for WBR in that increased psychological scores were associated with larger negative discrepancies between perceived and ideal WBR (smaller waist relative to bust – a ‘curvy upper body’).

The relationships between BMI/WHR/WBR BD and ‘psych’ were no longer significant when considering the high and low concerns groups separately (all *p*s > .05), except for the relationship between BMI BD and ‘psych’ for the high concerns group ($r_s = -.32$, $p = .050$) and this remained significant when controlling for actual BMI ($r_s = -.43$, $p = .008$). This suggests that for those with already heightened body concerns, the discrepancy between perceived and ideal BMI (toward desiring an ideal which is smaller than their perceived current body size) is associated with increased psychological concerns.

Figure 3.15

The relationship between psychological concerns and the discrepancy between perceived current and ideal BMI (BMI BD), with coloured points denoting the group of each data point.



A multiple linear regression was used to predict BMI BD (the discrepancy between perceived and ideal body size) from ‘psych’, group (high vs low) and actual BMI ($F(3, 64) = 27.32$, $p < .001$, $R^2 = .54$). There was a significant main effect of BMI ($B = -0.42$, $t = -5.70$, $p < .001$). There were no significant effects of ‘psych’ or group. This indicates that for every increase of the women’s BMI there was a decrease of approximately 0.42 BMI for the difference between their ideal and perceived body size, such that those with higher BMIs desired an ideal BMI lower than their perceived BMI (see Figure 3.14), irrespective of body and psychological concerns. Although, it should be noted that BMI BD is not normally distributed and despite a significant relationship with actual BMI (determined using Spearman's Rank correlations), this result should be interpreted with caution.

3.9.4 *Interactive 3D Body Size/Shape Estimates (PCA)*

A PCA of the 3D body shapes was used to explore perceived and ideal body size/shape, going beyond the four size/shape variables presented in the previous section, which may not have captured specific features of body shape and composition (e.g. fat deposition, muscularity or tone, breast/buttock 'firmness' etc.). The PCA revealed that only four Principal Components (PCs) were needed to capture 95% of the variance. Factor scores on each of the four PCs for each body estimation (perceived current and ideal) were used in subsequent analyses.

Description of the PCs. To understand what body size/shape variance each of the PCs were capturing, visualisations of the predicted body shapes at high and low levels (+/- 5 SD) of each PC were used for illustration so that a qualitative description could be formed (Figure 3.16). Furthermore, PC scores for both perceived current and ideal bodies were correlated with the measurements taken from the bodies (perceived and ideal BMI/WHR/WBR/BHR; see Section 3.9.3) to gain further understanding of how the PCs relate to the manual measurements (see Table D.5, Appendix D for correlation coefficients and significance values). Based on these, the following descriptions of each PC were formed:

PC1 – overall body size/shape. Lower scores indicate a smaller overall body size/shape and higher scores indicate increased overall size/shape.

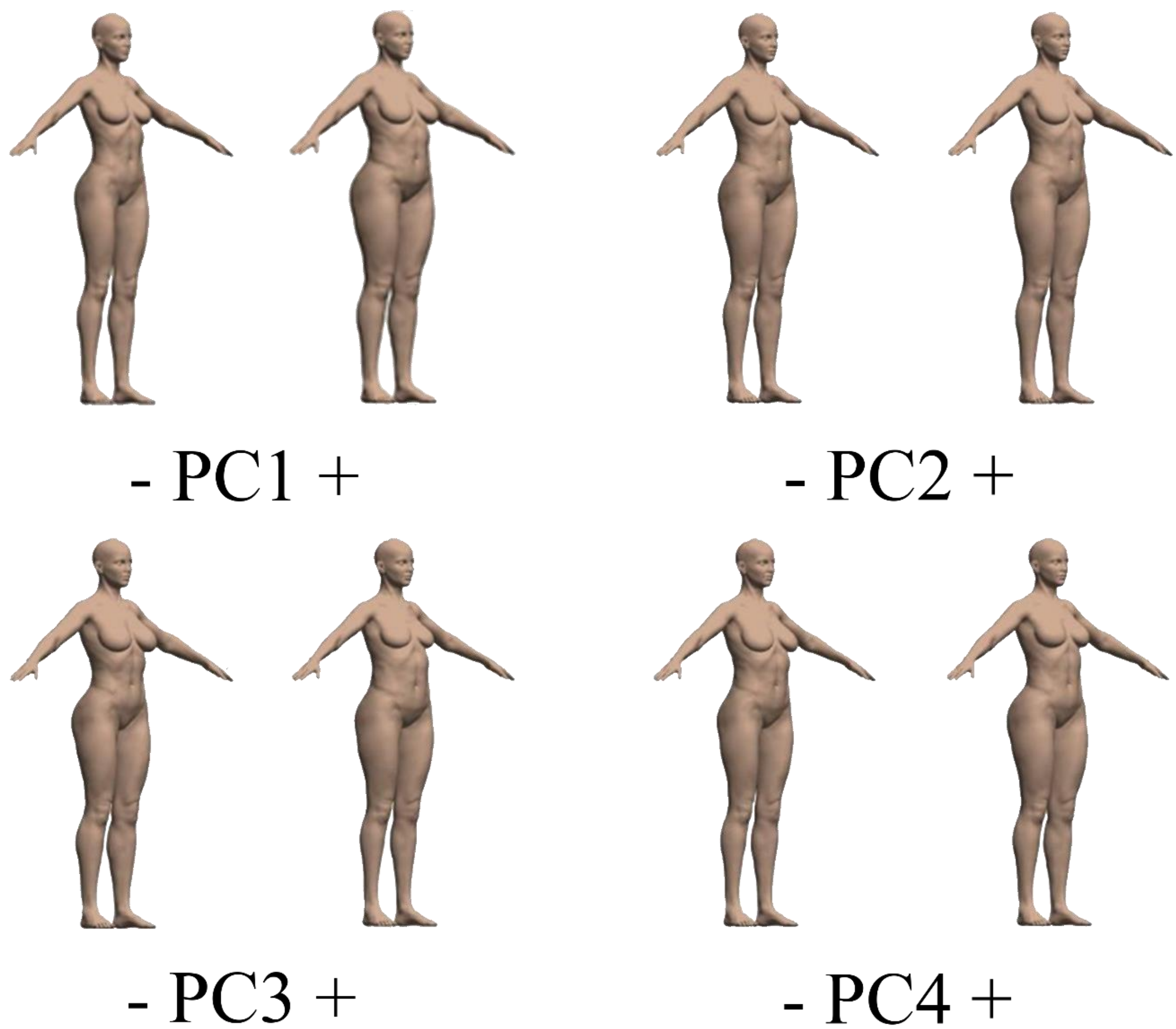
PC2 – upper body width. Lower scores indicate decreased upper body/bust width and a less curvaceous/straighter body shape. Higher scores indicate increased upper body/bust width and a more curvaceous body.

PC3 – stomach flatness and bust size. Lower scores indicate increased stomach flatness, increased bust size, rounded glutes and decreased waist width toward a more curvaceous, ‘hourglass’ figure. Higher scores indicate a less ‘hourglass’ figure, smaller breast and glute size and a rounder stomach.

PC4 – body firmness (i.e. breast pertness and lower body thickness). Lower scores indicate perter breasts and increased lower body thickness (wider hips/upper thighs and rounder glutes). Higher scores indicate less pert breasts and decreased lower body thickness.

Figure 3.16

Visualisations of the predicted body shapes at high and low levels (+/- 5 SD) of each Principal Component (PC).



Perceived Current and Ideal 3D Body Shape. Factor scores for PCs 1, 3 and 4 were normally distributed (Shapiro-Wilk tests; *p*s > .05), however, PC2 scores violated the assumption of normality ($p < .05$). A summary of the descriptive statistics for each PC, for both perceived and ideal bodies, are presented in Table 3.12 for each group separately, and the significance value of between-group comparisons are reported.

There were significant differences between perceived current and ideal PC1 scores for both the low concerns ($t(29) = 3.51$, $p = .002$) and high concerns ($t(37) = 10.07$, $p < .001$) groups, indicating that both groups desired an overall body size/shape smaller than their own, corroborating the BD findings using measurements (presented in Table 3.11). There were significant between-group differences on PC1 for both perceived current and ideal bodies, such that the high concerns group had significantly higher scores for their perceived current and ideal body estimates (i.e. an increased overall body size/shape compared to the low concerns group) (see Table 3.12). Again, this corroborates the findings presented earlier using the Daz body measurements (see Tables 3.8 and 3.10), where the high concerns group had significantly higher perceived body size (BMI), WHR and WBR, and lower BHR, and the low concerns group desired a significantly lower ideal body size (BMI) and higher BHR.

For PC2, there were no significant differences between perceived current and ideal scores for both the low concerns ($V = 271$, $p > .05$) and high concerns ($V = 446$, $p > .05$) groups, determined using a Wilcoxon Signed-Rank test on paired samples. This indicates that there was no difference between perceived and ideal upper body width. However, for the ideal bodies, there was a significant between-group difference, where the high concerns group desired a significantly narrower upper body width than the low concerns group (see Table 2.12). This finding reflects differences in ideal BHR (presented in Table 3.10), where the high concerns group desired a significantly lower BHR (indicating a desire for a ‘pear-shaped’ figure where the hips/buttocks are fuller/wider relative to the bust).

For PC3, there were significant differences between perceived current and ideal scores for both the low concerns ($t(29) = 3.19$, $p = .004$) and high concerns ($t(37) = 3.33$, $p = .002$) groups, such that the ideal bodies had significantly lower scores than the perceived. Both groups, on average, had negative scores on PC3 for their ideal bodies, representing a desire for increased body firmness (e.g. a flat stomach, decreased waist width, larger bust size, and rounded glutes) compared to their perceived. There were no significant between-group differences for perceived current or ideal PC3 scores, indicating no differences between the high and low concerns groups for perceived or ideal levels of body firmness.

For PC4, there was a significant difference between perceived current and ideal scores for the low concerns group ($t(29) = 3.22$, $p = .003$), where ideal scores were significantly lower, indicating a desire for increased breast pertness and lower body thickness. The high concerns group perceived themselves as having a more pert/thick body compared to the low concerns group (see Table 3.12), but did not desire a significantly different level of pertness/thickness compared to their perceived ($t(37) = 0.48$, $p > .05$).

Table 3.12

Descriptive statistics (mean, standard deviation, minimum, and maximum) of each Principal Component (PC) and between-groups differences.

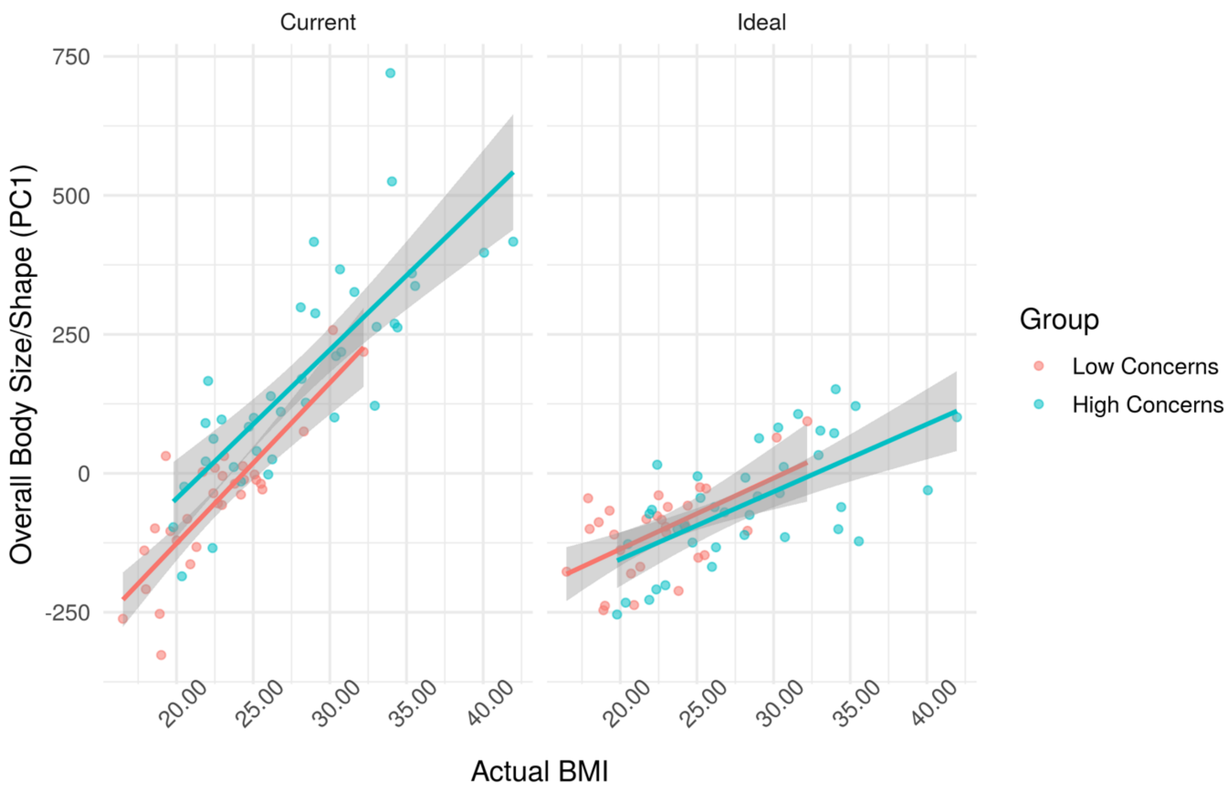
PCs	Low Concerns		High Concerns		High vs Low
	M (SD)	Range	*M* (SD)	Range	*p*
			Current		
PC1	-51.08 (123.55)	-326.89 – 257.76	175.89 (188.52)	-185.24 – 720.00	< .001
PC2	9.74 (65.70)	-142.49 – 169.95	-1.76 (60.06)	-150.92 – 151.58	> .05
PC3	11.20 (23.68)	-50.12 – 48.63	7.41 (34.18)	-70.25 – 91.58	> .05
PC4	10.47 (16.12)	-26.22 – 39.42	-2.24 (31.85)	-82.72 – 64.08	.037
			Ideal		
PC1	-103.18 (79.39)	-246.22 – 93.69	-54.10 (104.80)	-253.93 – 151.31	.032
PC2	9.77 (46.44)	-51.45 – 133.30	-13.64 (40.07)	-67.83 – 88.86	.017
PC3	-6.20 (24.89)	-69.63 – 46.12	-11.36 (28.50)	-65.58 – 40.55	> .05

PCs	Low Concerns		High Concerns		High vs Low
	M (SD)	Range	*M* (SD)	Range	*p*
PC4	-1.54 (23.44)	-69.08 – 39.05	-4.81 (23.05)	-51.05 – 34.89	> .05

Only PC1 scores significantly correlated with actual BMI (perceived current, r_s = .86, p < .001; ideal, r_s = .60, p < .001). Both correlations were positive, indicating that an increase in actual BMI was associated with increased overall body size/shape, for both perceived and ideal body estimates. The correlations remained significant when considering both low (perceived current, r_s = .75, p < .001; ideal, r_s = .41, p = .023) and high (perceived current, r_s = .85, p < .001; ideal, r_s = .63, p < .001) concerns groups separately. This shows that for women with both high and low/mild levels of body concerns, those with higher BMIs perceived themselves as having a larger overall body size/shape and desired a larger overall body size/shape (see Figure 3.17). Again, this corroborates findings that perceived current body size/shape variables from the measurements are associated with the individual's own BMI, as is ideal BMI (see Section 3.9.3).

Figure 3.17

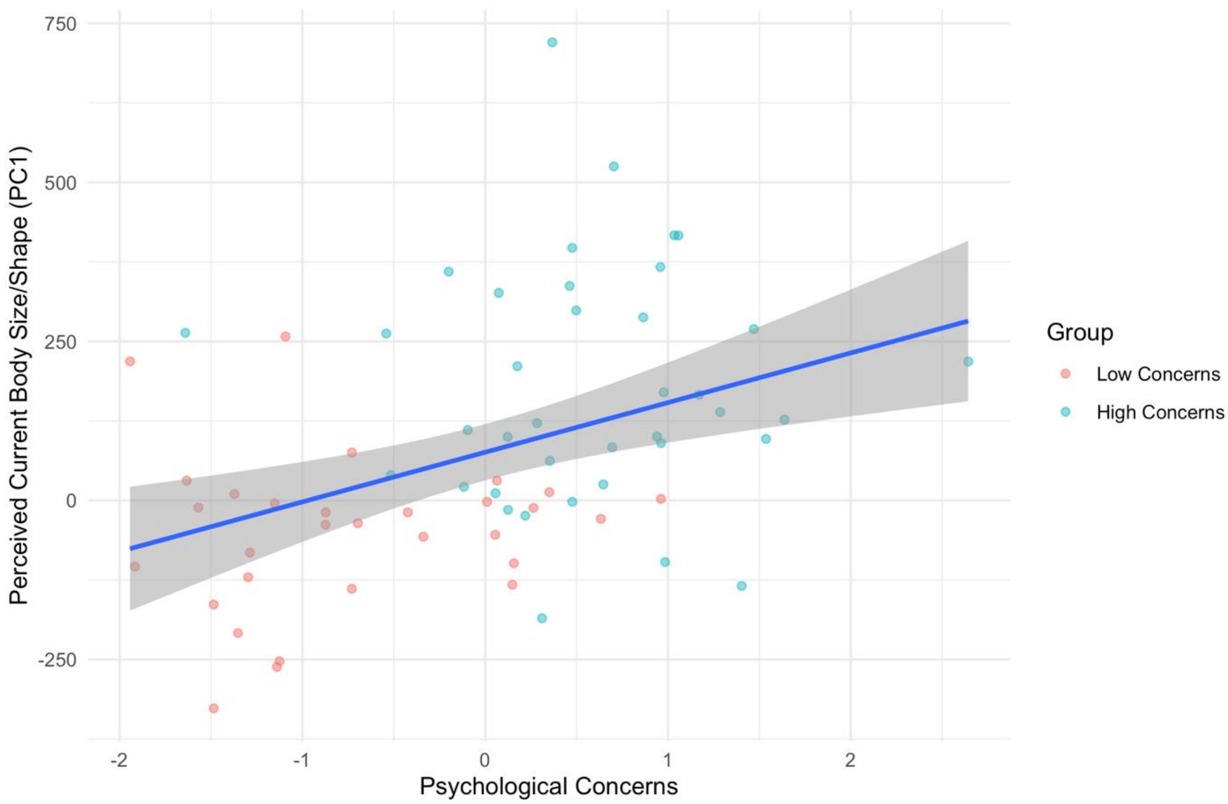
The relationship between Principal Component 1 scores (a reflection of overall body/size shape) (y-axis) and actual BMI (x-axis), for perceived current (left) and ideal (right) body shapes.



For the whole sample, there was a significant positive correlation between ‘psych’ and perceived current PC1 scores ($r = .39$, $p = .001$). This indicates that increased psychological concerns were associated with increased perceived overall/body size and shape (see Figure 3.18), such that those with higher concerns perceived themselves as being larger. The relationship was no longer significant when controlling for actual BMI ($r = .24$, $p = .054$). There was a significant negative correlation between ‘psych’ and ideal PC2 ($r_s = -.27$, $p = .024$), which remained significant when controlling for actual BMI ($r_s = -.32$, $p = .001$), indicating that as psychological concerns increased there was a decrease in ideal upper body width representing a desire for a narrower upper body or a more ‘pear-shaped’ figure. When considering the groups separately, the correlations were no longer significant and there were no significant correlations between ‘psych’ and the other PCs (all *p*s > .05).

Figure 3.18

The relationship between perceived current body size/shape (Principal Component 1) and psychological concerns, with coloured points denoting each group.



Like the analyses for the measurement variables, multiple regressions were used to predict scores on each PC. For PC1, separate linear regressions were calculated predicting perceived current scores ($F(3, 64) = 69.13$, $p < .001$, $R^2 = .75$) and ideal scores ($F(3, 64) = 17.52$, $p < .001$, $R^2 = .43$) from actual BMI, group and ‘psych’. For perceived current shape, there was a significant main effect of actual BMI ($B = 27.30$, $t = 10.85$, $p < .001$). There were no significant effects of ‘psych’ or group. Similarly, for ideal body shape, there was a significant main effect of actual BMI ($B = 12.27$, $t = 6.52$, $p < .001$). There were no significant effects of ‘psych’ or group. This indicates that for every increase of the women’s BMI there was an increase in both perceived and ideal overall body size/shape, irrespective of body and psychological concerns. These findings support the previous findings using the estimated BMI of the perceived current and ideal bodies, in that actual BMI significantly influences both the perceived current and ideal BMI (demonstrated in Figure 3.17).

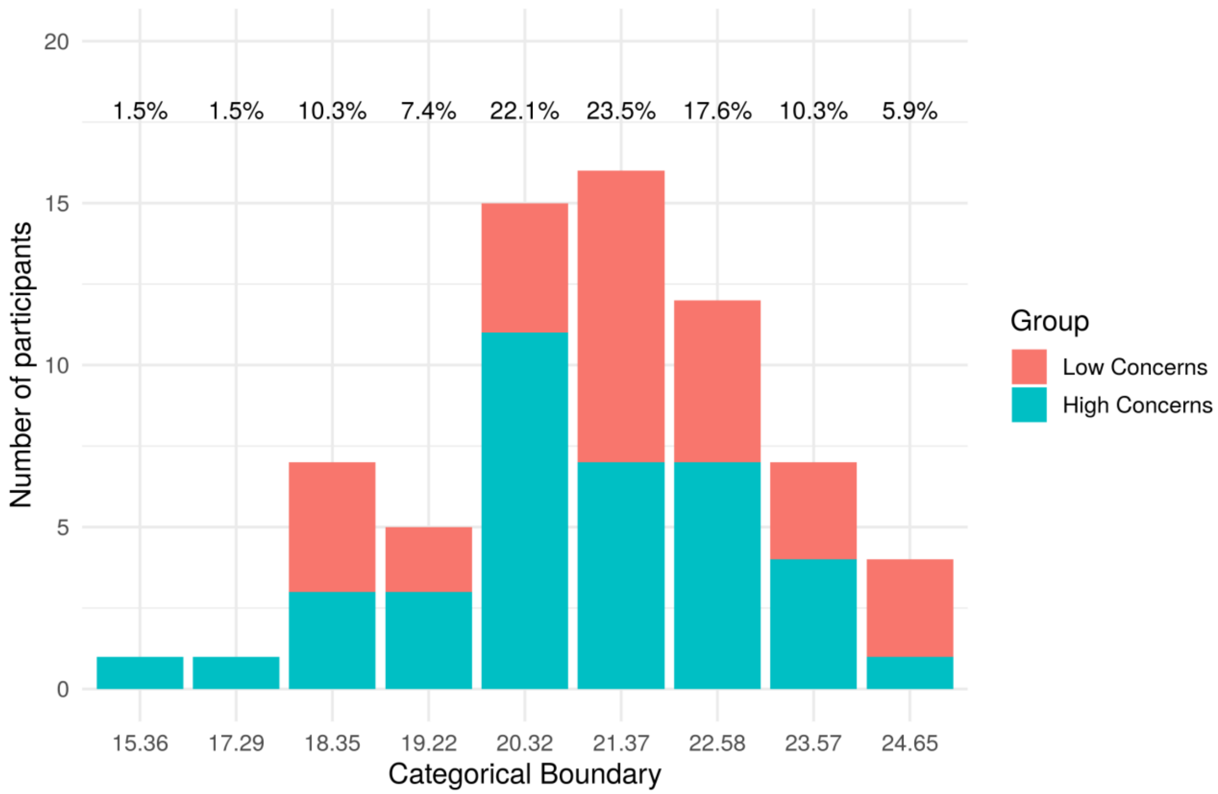
For PCs 2, 3 and 4 (perceived current and ideal), the linear regressions models were not significant (*p*s > .05).

3.9.5 *Categorical Boundary*

Overall, for the whole sample, the mean categorical boundary was 21.15 ($SD = 1.92$). There was no significant difference between the categorical boundaries of the high concerns ($M = 20.93$, $SD = 1.94$, range = 15.36 - 24.65) and low concerns ($M = 21.43$, $SD = 1.89$, range = 18.35 - 24.65) groups, $Z = 648.50$, $p > .05$. This demonstrates that for both groups, the BMI boundary at which the bodies were considered fat was similar, irrespective of body concerns. For both groups, the boundary was in the normal BMI category. None of the participant’s categorical boundaries was in the overweight or obese BMI categories, indicating that the boundary between thin/fat for women with both high and low body concerns is in the normal weight or underweight BMI range. Figure 3.19 presents the frequency of categorical boundary responses according to stimulus BMI, with coloured bars showing the split per group.

Figure 3.19

The number (y-axis) and percentage of participants for each categorical boundary BMI with coloured bars showing split per high/low concerns group.



The categorical boundary for the whole sample was, on average, significantly higher than the average ideal BMI (19.55), $V = 2055$, $p < .001$. This was the case for the low concerns group (ideal BMI 18.71), $V = 455$, $p < .001$, and the high concerns group (ideal BMI 20.22), $V = 563$, $p = .005$. This implies that their categorical thin-fat boundary was significantly higher than their ideal body size, such that according to the categorical boundary the women's ideal bodies would be classed as thin. However, there was no significant correlation between categorical boundary and ideal BMI from the Daz interactive body size/shape estimates ($p > .05$), indicating there was no systematic consistency between the measures, such that as ideal BMI increased the thin/fat boundary did not also increase.

In relation to the sample's actual BMI (presented in Table 3.7), the categorical boundary was significantly lower in BMI ($V = 0.00$, $p < .001$, $M_{\text{Diff}} = -4.62$). This was the case for both low ($V = 78.00$, $p = .002$, $M_{\text{Diff}} = -1.17$) and high ($V = 0.00$, $p < .001$, $M_{\text{Diff}} = -7.34$) concerns groups, thus, according to the categorical boundary the women in this study would class themselves as 'fat'. As demonstrated by the Mean Differences, the categorical boundary for the high concerns group was much lower compared to their actual BMI. There was significant no correlation between categorical boundary and actual BMI ($p > .05$), indicating there was no systematic consistency between the measures, such that as actual BMI increased the thin/fat boundary did not also increase in BMI.

For the whole sample, there was a significant negative correlation between categorical boundary and current PC2 ($r_s = -.27$, $p = .029$), which remained significant when controlling for actual BMI ($r_s = -.27$, $p = .028$). This indicates that as categorical boundary BMI increased, there was a decrease in perceived upper width (i.e. a less curvaceous upper body shape). This relationship remained significant when considering only the low concerns group ($r_s = -.50$, $p = .005$). For this group, there were also significant negative correlations between categorical boundary and current PC3 ($r_s = -.41$, $p = .023$) and ideal PC2 ($r_s = -.49$, $p = .007$). These relationships remained significant when controlling for BMI (ps < .05). This indicates that higher thin/fat boundaries were associated with decreased perceived and ideal chest width (narrower upper body) and increased perceived stomach flatness and bust size. For the high concerns group, categorical boundary significantly positively correlated with WHR BID (the discrepancy between perceived and actual WHR; $r_s = .43$, $p = .007$), remaining significant when controlling for actual BMI ($r_s = .46$, $p = .004$). This suggests that an increase in BMI of the boundary between thin and fat was associated with overestimation of WHR, whereas underestimation of WHR was associated with decreased boundary BMI. There were no other significant correlations between categorical boundary and any of the Daz body size/shape variables, age, BMI, or psychological concerns for the whole sample or when considering each group separately (all *p*s > .05).

Summary of Results

These findings demonstrate the relationships between perceptual body size/shape estimations, actual body size/shape, and broader psychological concerns in a sample of non-eating disordered females with differing levels of body concerns. As expected, the high body concerns group reported significantly higher overall psychological concerns and had significantly higher BMIs, compared to the low body concerns group. No differences in categorical perceptions of 'thin' and 'fat' body sizes were found. The most notable finding from this study was that the women's actual BMI tended to be most strongly related to perceptual body image, irrespective of body/psychological concerns, using both estimated BMI and scores from a novel PCA analysis. This highlights the importance of taking into consideration the individuals own body size/shape when assessing perceptual body image

3.10 Discussion

In this chapter, I have attempted to replicate a categorical perceptual training intervention which aimed to shift the boundary between 'thin' and 'fat' body size higher in the BMI spectrum so that fewer bodies were considered 'fat', using a CBM task with written feedback. The longer-lasting effects (up to 30 days) were examined. Previous work found it to be successful in samples of women with high body concerns (Gledhill et al., 2017; Irvine et al., 2020; Szostak, 2018). This research found that the task could successfully shift the categorical thin/fat boundary higher up in the BMI spectrum by approximately 5 BMI units, from the low end of the normal BMI category to just over the boundary of the overweight BMI category post-training, which was maintained up to the 30-day follow-up. There was also an increase in the thin/fat boundary of the control group, who received feedback that was consistent with their categorical responses on the day, although this was a smaller increase than the intervention group's (approximately 2.26 BMI units). This meant that their boundary remained in the low-mid normal BMI range throughout the study. Both groups boundaries did not significantly change from day 4 to day 30, indicating that perceptions were maintained.

The previous investigations of this intervention in 2D and VR found reductions in psychological concerns in the intervention compared to the control group. However, in this study, there was no effect of condition on psychological concerns. There was evidence that psychological concerns decreased at day 4 compared to day 1 for both groups, and compared to day 4 their scores at follow-up (days 15 and 30) were similar. Szostak (2018) also found decreases in measures of disordered eating for the control group. One reason for this may be attributed to repeated measurements (see e.g. Sharpe & Gilbert, 1998). Another explanation is that although the CBM protocol may produce a change in perceptual interpretations of ambiguous stimuli (i.e. thin/fat boundary) it may not generalise to broader cognitive-affective outcomes (Hiemstra et al., 2019; Rawdon et al., 2018). There were no correlations between thin/fat categorical boundary and psychological concerns at baseline (for both high and low concerns) or follow-ups (for high concerns), indicating that categorisations are not necessarily related to psychological concerns. Moreover, the influence of demand characteristics cannot be ignored as participants may have responded in a favourable way (Hiemstra et al., 2019). In this research, no data regarding participant's awareness of the manipulation or their condition allocation was collected. The impact of participants awareness of intervention intentions on CBM intervention efficacy remains unclear, with some evidence suggesting that awareness enhances bias modification and symptom change (Mobini et al., 2014). The effects of awareness in this intervention are currently unknown and future research using this intervention should attempt to develop understanding of this. Additionally, further investigation is warranted to determine the clinical effectiveness and generalisability of such CBM training protocols to cognitive-affective outcomes in both clinical and non-clinical settings, emphasising the importance of intervention replications and trials.

The applicability and ecological validity of stimulus duration (150ms) in the CBM task may be questioned. This was used to promote automatic categorisation of body size, however, the trial in immersive VR indicates that 3D life-size presentation of the body stimuli combined with unrestricted viewing time was beneficial and produced stronger effects that were clinically meaningful (Irvine et al., 2020). Together, the VR protocol provides a more ecologically valid experience (we are typically used to seeing bodies life-sized in 3D for longer than 150ms), however, the exact aspect (life-size 3D vs stimuli duration) which produces a stronger effect is unknown. Therefore, future work should trial the 2D version with an unrestricted viewing time of each stimulus to allow a direct comparison.

Furthermore, although links between perceptions of body size generally and self-specific perception/ideals have been implied (e.g. Bould et al., 2018; Challinor et al., 2017) and evidence suggests that changes in ‘visual diet’ alter perceptions of ‘normal’ body size, preferences and ideals (Boothroyd et al., 2012; Thornborrow et al., 2018; Tovée et al., 2006). There is no evidence that manipulating general perceptions of body size in an experimental setting will have a lasting impact on self-specific judgements. Bould et al. (2018) found that experimental exposure to overweight bodies impacted the individuals own body size perceptions immediately after, but this was no longer evident at a 24-hour follow-up. In Study 1, we did not find changes in body size/shape estimations at the 30-day follow-up compared to day 1, for either condition. Szostak (2018) did find that the BMI of the most ideal/attractive body increased post-training (and was maintained at the two-week follow-up) for the intervention group, indicating that as the perception of thin increased in BMI as did the most ideal/attractive BMI. This research did not find any shift in ideal body size/shape. Szostak (2018) used the body stimuli from the CBM task and asked participants to rate how close each was to their body ideal (using a 1 - 9 scale), whereas this research used an interactive approach which allowed participants to alter the size and shape of a 3D model. This method allowed the participants more control and personalisation over the size *and* shape of the body estimations that were not constrained by a set of given images varying in BMI, which may be argued is more specific to the individual. Nevertheless, despite the post-training categorical boundary increasing (maintained at both follow-up days), only measuring self-specific body size/shape estimations at day 30 may have been too late for changes to be evident. Moreover, it has been said that clinical and subclinical samples are potentially more resistant to change (see e.g. Glauert et al., 2009; Szostak, 2018; Wedell et al., 2005). It is possible that body ideals and distortions are so engrained that this protocol may alter general perceptions of thin/fat but not self-specific perceptual body image. The body size/shape estimations were fairly consistent across sessions and there was no significant relationship with categorical boundary. The findings indicate that perceptual body image was related to and predicted by the individual's BMI which did not significantly change over the 30 days, which may in part explain why there were no differences despite changes in categorical thin/fat boundaries.

In both studies 1 and 2, the body size/shape estimations (perceived and ideal) were significantly related to the participant's own body size/shape, for example, those with higher BMIs also perceived themselves as having a higher BMI and desired a higher BMI body. Irrespective of body concerns, the average ideal body size and WHR reflected previous research showing that the ideal body size is between 18 - 20 BMI units and has a WHR of 0.70 (Hildebrandt & Walker, 2006; Singh, 1993; Tovée et al., 2002). Ideals tended to be lower in BMI compared to perceived and there was a tendency to a desire a more curvaceous body shape, with larger bust/hips and a smaller waist, which is consistent with studies of female attractiveness (Fisher & Voracek, 2006; Singh & Young, 1995) and previous findings using a similar approach (Crossley et al., 2012). This indicates that female body size/shape ideals are pervasive and are largely consistent across women with differing level of body concerns, modulated by actual body size/shape. Although it is important to distinguish that participants were creating *their* ideal body size/shape, which they may implicitly relate to their existing size/shape (self-specific), future work may seek to investigate how wording/phrasing influences responses. Some research using figural rating scales varying in BMI indicate the phrasing (e.g. your ideal vs ideal woman) does not significantly influence selection (Fingeret et al., 2004). Similarly, there were no significant differences in accuracy of perceived size/shape as a function of psychological concerns, instead, these findings provide compelling evidence for contraction bias in that those with higher BMIs tended to underestimate and those with lower BMIs tended to overestimate, consistent with previous findings (Cornelissen et al., 2015; Cornelissen et al., 2013; Irvine et al., 2019; Vartanian & Germeroth, 2011). On average, women with high body concerns had significantly higher BMIs and increased psychological concerns compared to those with low body concerns. These findings demonstrate that BMI is strongly related to perceptual body image, ideals, and size/shape dissatisfaction, which should be considered in future research and in healthcare settings.

Notably, in Study 2, a novel analysis of the 3D body shapes was conducted using PCA to enable a more holistic understanding of size/shape beyond the estimated BMI and circumference measurements (WHR/WBR/BHR) taken manually from the 3D body estimations. The first PC (capturing overall body size/shape) was significantly related to the manual measurements and produced comparable findings. However, it did appear that some of the PCs captured variation in body shape and composition (e.g. stomach flatness, breast/buttock pertness, and body 'firmness') which were not captured by the manual measurements. This novel approach provides a relatively fast, easy, and efficient way to analyse 3D body shape created using an interactive methodology, which may provide a useful tool for assessment of perceptual body image. This approach may enable researchers to capture a more detailed and nuanced understanding compared to traditional methods (e.g. BMI figural rating scales) which only capture variation on the one dimension, although it is a comparatively more time consuming and technically advanced approach which may be less useful in clinical settings or research where computer access is limited.

In conclusion, a replication and extension of a CBM intervention for women with high body concerns was conducted, to advance understanding of the longer-lasting effects and its relationship to the individuals own perceptual body image. The results indicate that the intervention does successfully shift the thin/fat categorical boundary for those receiving the inflationary feedback (intervention), more so than controls, and this increase was maintained at the two-week and one-month follow-up dates. Decreases in psychological concerns across the course of the intervention were observed in both the intervention and control groups and general perceptions of 'thin' and 'fat' were not related to psychological concerns. There were no significant changes in perceptual body image post-intervention or associations with general perceptions of ‘thin’ and ‘fat’. The findings from women with both high and low body concerns (Study 2) indicate that perceptual body image is largely related to their own body size/shape, more than psychological/body concerns, highlighting the importance of taking the individuals own body size/shape into account. Overall, this research has revealed interesting relationships between categorical perceptions of body size, body and psychological concerns, self-specific perceptions of body size/shape, and the person’s own body size/shape, and has introduced a novel analysis for 3D body shapes.

Chapter 4: (Studies 3 & 4): The Development and Validation of Perceptually-Spaced Figural Rating Scales Using Computer-Generated Stimuli Calibrated for BMI, for Assessment of Body Image

4.1 Introduction

Figural Rating Scales (FRS) are a popular and widely used technique for the visual assessment of body size/shape perception. Due to the popularity of this technique and the applicability across settings, an abundance of FRS have been created, although there are methodological issues regarding stimuli standardisation, realism and ecological validity, scale coarseness, and the spacing between adjacent bodies (Gardner & Brown, 2010a; Gardner et al., 1998).

First, many FRS present bodies in front-view which reduce the availability of key weight/shape cues, such as stomach depth, which affects body size estimation precision and discrimination accuracy (Cornelissen et al., 2018). The majority of FRS use silhouette or line drawings which are not realistic representations of human bodies e.g. some missing facial features (eyes and mouth), poorly defined body features, and disproportionate body parts (Thompson & Gray, 1995). A review by Gardner and Brown (2010a) shows that FRS are often based on artistic impressions which subjectively represent a variety of body sizes rather than known body measurements for each body size. Fewer scales are based on known anthropometric measurements (e.g. Gardner et al., 2009), which presumably provide a more accurate representation of body size/shape.

Some modern FRS are created using Computer-Generated (CG) body stimuli as they are high-quality, standardised, photorealistic, and can be based on anthropometric measurements

(Cornelissen et al., 2016), providing more ecologically valid stimuli than traditional silhouette/line drawing scales (Mutale et al., 2016). Despite these advantages, recent findings suggest that CG bodies were not processed in the same way as real bodies, as they were subject to increased serial dependency bias (errors in perceptual judgements of body size in the direction of the previously viewed body size) and poorer discrimination (Alexi et al., 2019). However, these images were based on replicating body size/shape from photographs of people (not a statistical calibration for BMI), they were not standardised (i.e. each had different poses, clothing and skin tones), and the quality of the images were less photorealistic than the ones created for this research (see Section 1.5.2, Chapter 1 for more details). Further investigation of perceptual discriminability using standardised CG stimulus is warranted when developing FRS, to ensure that people can discriminate between body sizes across the BMI spectrum.

Second, the spacing between adjacent bodies is often not well documented, with no theoretical or *a priori* justification. Some have utilised constant spacing as recommended by Gardner et al. (1998). For example, Gardner et al. (2009) created a FRS based on measurements from a large anthropometric survey. The silhouettes ranged from -60% to +140% of the average body weight/shape, with 5% changes in weight values between adjacent bodies, corresponding to approximately 1.40 BMI units (calculated using weight values for each body based on the average weight and height). However, a common perceptual phenomenon known as ‘Weber’s law’ may impede the ability to discriminate between constant body size changes across the BMI spectrum. Weber’s law states that the smallest difference between a pair of stimuli that can be identified is a constant proportion of the stimulus magnitude (Gescheider, 1997). Based on linear increases in BMI, this would suggest that larger BMI differences are required as BMI increases for the difference to be reliably detected. This has been supported by empirical research using CG stimuli calibrated to increase linearly in BMI (Cornelissen et al., 2018; Cornelissen et al., 2016). Using a constant change between adjacent stimuli in FRS fails to account for this phenomenon, meaning that differences between adjacent stimuli that are noticeable at the lower end of the BMI spectrum might not be noticeable as BMI increases. Implications of this are under- or over-representation of bodies in a particular BMI category and confusion when making estimates if changes between body sizes are undetectable or too large, potentially yielding inaccurate responses. Using spacing based on Weber’s law may lead to more precise body size judgements (Cornelissen et al., 2018).

Lastly, the optimal number of stimuli is unknown. Existing FRS typically consist of seven to nine bodies (Gardner & Brown, 2010a; Gardner et al., 1998), with some research suggesting that seven plus or minus two is optimal, based on testing FRS with either three, five, seven, or nine bodies (Ambrosi-Randić et al., 2005). Gardner et al. (1999) argue that this results in scale coarseness, which is unlikely to capture the person’s true response and potentially yields inaccurate responses. If there are a lack of bodies representing what a person believes is closest to their actual/ideal body size, the person is forced to choose a response even if it does not reflect their actual choice. Accordingly, larger FRS with small differences between adjacent bodies should be used (Gardner et al., 1999). Though practically, for application in healthcare/clinical settings, those containing fewer selections may be more useful due to ease and flexibility in administration, space, and portability. Some studies have shown that participants responses are limited to a small subset of the possible choices (approximately three) (Gardner & Brown, 2010a; Zaccagni et al., 2020) and few participants select body sizes at the extreme ends (Ambrosi-Randić et al., 2005; Must et al., 2002), suggesting that responses are limited even when given a larger range of options and this is likely to inflate test-retest reliability findings (Gardner et al., 1998).

Some authors have proposed using continuous approaches which are not limited by discrete options (Gardner et al., 1998). When applied to FRS, some continuous scales only present body images at either end of the spectrum (the lowest and highest body sizes), for example, the ‘body line’ visual analogue scale (Alexi et al., 2018; Alexi et al., 2019) and the ‘analogue contour drawing rating scale’ (Gardner et al., 1999). These scales leave respondents to infer the body sizes between the extremes of the scale, which may make it difficult to visualise and choose their actual response accurately. In this research, it is proposed that a continuous approach providing real-time feedback, like a method of adjustment paradigm (Cornelissen et al., 2017), allow the benefits of a continuous approach without requiring inference and may therefore be a suitable option for future assessment of perceptual body image.

Consequently, there are many questions relating to FRS that remain unanswered. This current research aimed to explore some of those questions, using theory-driven recommendations and data to create and validate novel FRS. First, a set of CG stimuli calibrated for BMI were created (Section 2.3, Chapter 2). This stimulus set was then used to determine the Just Noticeable Difference (JND) across the BMI spectrum (Study 3). Three FRS were then developed, and the reliability and validity were assessed, as recommended by Stunkard (2000) (Study 4). Two discrete FRS were created with different numbers of bodies, both with spacing based on the JND. A continuous FRS using a method of adjustment paradigm was developed to allow for estimations that were not limited by discrete options, potentially enabling a more accurate reflection of the participant’s true response.

Study 3: Investigating Body Size Discrimination across the BMI spectrum; using Just Noticeable Differences.

4.2 Method

Ethical approval was gained from the School of Psychology Research and Ethics Committee at the University of Lincoln (Project code: PSY181949).

4.2.1 *Aim*

This study aimed to determine the smallest change in BMI that participants could detect (the JND) across the BMI spectrum.

4.2.2 *Participants*

Participants were recruited through opportunity sampling (students and staff) at the University of Lincoln and recruitment of undergraduate students in return for course credit. A total of 41 females (cis/as assigned at birth) aged 18 - 42 (*M* = 25.20, *SD* = 6.80), with no history or diagnosis of an eating disorder were recruited. The sample was predominately Caucasian (92.68%) with BMIs ranging from 17.54 - 40.03 (*M* = 24.25, *SD* = 5.31).

4.2.3 *Materials*

Computer Generated Body Stimulus. A series of 113 CG female bodies varying in BMI from 15.00 (underweight) to 43.00 (obese class III) in increments of 0.25 BMI units were used. These were created using Daz3D Studio and were calibrated for BMI, based on Health Survey for England data (HSE, 2008). See Section 2.3, Chapter 2 for details of stimulus creation and calibration.

Psychophysical JND task. This experiment used a 2-alternative forced-choice (2AFC), method of constant stimuli, psychophysical paradigm. Using this paradigm, one constant ‘base’ image was presented whilst manipulating the second ‘comparative’ image, in this case, for BMI.

Participants were presented with two images simultaneously on the screen (one base and one comparative body). They were asked to decide which of the pair was ‘larger’, in other words, higher in BMI, using a keypress (left arrow key for the body on the left side and right arrow key for the body on the right side of the screen) (see Figure 4.1). Each presentation was displayed for 2.5 seconds before showing a blank grey screen. Participants were able to make their response while the stimulus was being displayed on-screen or while the screen was blank. Participants were required to make a response for the next trial to occur.

Figure 4.1

An example of the psychophysical Just Noticeable Difference task instructions presented at the start of the task and the protocol for a single trial.

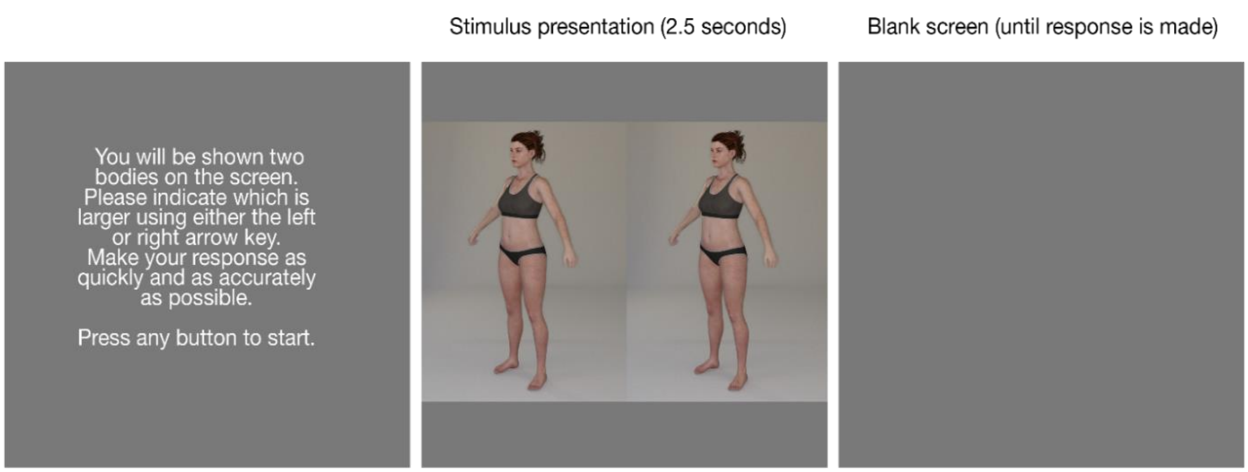


Image pairings were shown in eight blocks which correspond to eight BMI ranges. The base body was the image corresponding to the BMI in the middle of the block. This allowed for the identification of the JND within BMI categories (underweight, normal weight, overweight, and obese) and on the boundary of the BMI categories (e.g. in block 2 the base body was 18.50 BMI units which is the boundary of underweight and normal weight). A summary of the blocks is presented in Table 4.1.

Table 4.1

Summary of the blocks in the psychophysical Just Noticeable Difference task.

	BMI ranges for the eight blocks			WHO BMI classification	
Block	Base BMI	Lowest BMI	Highest BMI		
1	16.50	15.00	18.00	UW	Within
2	18.50	16.50	20.50	UW – NW	Boundary
3	22.00	20.00	24.00	NW	Within
4	25.00	23.00	27.00	NW – OW	Boundary
5	27.50	24.50	30.50	OW	Within
6	30.00	27.00	33.00	OW – OB Class I	Boundary
7	35.00	32.00	38.00	OB Class I – OB Class II	Boundary
8	40.00	37.00	43.00	OB Class II – OB Class III	Boundary

Abbreviations. UW = Underweight, NW = Norma Weight, OW = Overweight, OB = Obese

The comparative image varied in BMI across the specified range, including the lowest and highest BMIs, in increments of 0.25 BMI units. All comparative images were presented in random order and each image pairing was presented 10 times. For example, in Block 1, the base body was a BMI of 16.50 and was compared to all comparative images in that range (13 pairings), resulting in a total of 130 trials. To limit biases, the base body was presented equally on the left and right side of the screen for each of the image pairings (i.e. five times on the left and five times on the right). Block presentation was randomised, with breaks after each block to limit effects from fatigue. This was programmed in MATLAB Version 2018a (The MathWorks Inc., 2018).

Psychometrics. To measure attitudinal body image, participants were asked to complete the psychometric measures detailed in Section 2.2, Chapter 2.

Body Measurements. Estimates of body composition and BMI were taken using the Tanita BIA scale, standing height using a stadiometer and circumference measurements using a tape measure (see Section 2.1, Chapter 2).

4.3 Procedure

After providing informed consent, participants were first asked to complete the psychophysical JND task on a 24” flat panel LCD screen in a university lab. Afterwards, participants completed demographic details (age, ethnicity, and history/current diagnosis of an eating disorder) and the psychometric measures using a Qualtrics form. Finally, body measurements were taken, and the participants were debriefed. The whole procedure took approximately 90 minutes.

4.4 Data analysis

The psychophysical data were analysed using ‘R Studio’ (Version 3.6.9), following a linear psychophysical approach detailed by Gescheider (1997). Firstly, the proportion of correct responses were calculated for each participant, for each block and each level of difference (the difference between the base and comparative stimulus). Proportion values were then converted to Z scores to create a linear psychometric function, which creates a standardised unit of measurement across the different blocks to allow comparison. The psychometric function was then determined using a linear regression model for each participant and block, to predict Z scores based on the comparison stimulus.

From the linear model, coefficient values for each participant in each block were obtained. An inclusion criterion of $R^2 > 0.25$ was used for each block so that models of participants' responses with R^2 below 0.25 were excluded from further analyses.

The JND, also known as the difference limen (DL), was calculated using the psychometric function and the point of subject equality (PSE). The PSE corresponds to a Z value of .50 on the psychometric function (i.e. a lack of discrimination, where the comparison and base stimuli are perceived as the same). The upper DL is the difference between the PSE to the .75 point (which corresponds to a Z value of .67 on the psychometric function) and the lower DL is the difference between the PSE to the .25 points (which corresponds to a Z value of .67 on the psychometric function). This gives two values: one DL above the PSE and one DL below the PSE. These two DL values were then averaged to determine the DL value for each participant, in each block (Gescheider, 1997).

Finally, following the statistical approach by Cornelissen et al. (2016), a linear mixed-effects model was run using the lmer function in the 'lme4' package (Bates et al., 2014) and the 'lmerTest' package (Kuznetsova et al., 2017) to get significance values for the fixed effect. The predicted DL values from the mixed-effect model were obtained using the coefficient and intercept of the fixed effect.

4.5 Results

First, a model was run including only a fixed effect of Base BMI, treated as a continuous variable (*AIC:* 521.70; *BIC:* 532.84). Secondly, a random-effects only model including only random effects of the participants on the intercept was run (*AIC*: 547.57; *BIC*: 558.71). Next, a full model including both fixed and random effects was run (*AIC*: 459.60; *BIC*: 474.46).

Comparisons of AIC and BIC values suggest that the full model was a better fit for the data due to decreased values. A Likelihood Ratio Test was used to compare the random effects only model to the full model, to identify whether model fit was significantly improved. The difference between these models was significant $\chi2(4) = 99.60$, $p < .001$, *AIC*: 446.56, *BIC*: 461.41, suggesting that the full model with both fixed and random effects included was a more accurate model fit for the data. The final model:

$$y_i = \beta_0 + \beta_1 x_1 + u_j + \epsilon_{ij}$$

y_i = DL, x_1 = Base BMI, u_j = random intercept of the participant, and ϵ_i = residual error.

There was a significant effect of Base BMI on DL, $F(1, 256.44) = 119.07$, $p < .001$. A full summary of the model is presented in Table 4.2.

Table 4.2

Summary table of the mixed-effect linear model of Difference Limen.

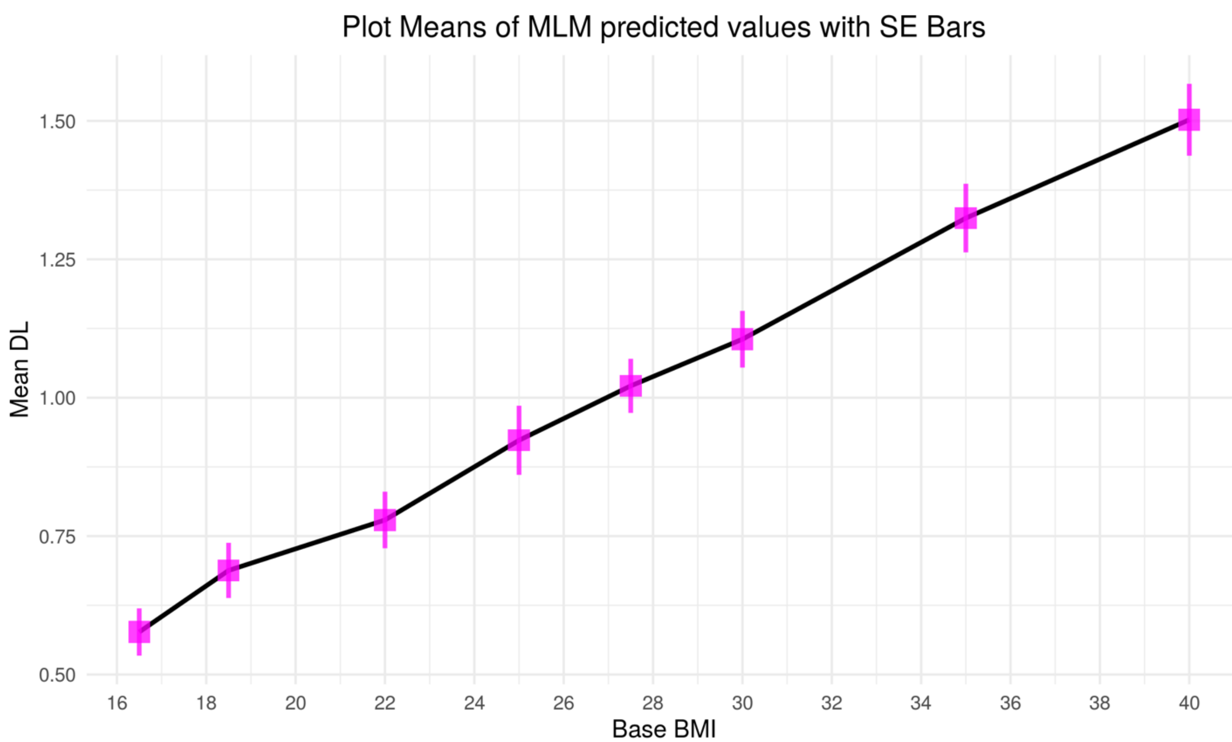
Fixed Effect	*b* Coefficient	*b* SE	*t*	*p*
(Intercept)	0.06	0.12	0.49	
Base BMI	0.04	0.003	10.91	< .001
Random Effect	Variance	SD	Correlation	
Participants (intercept)	0.18	0.42	-0.79	
Residual	0.19	0.44		

As predicted, the average DL increased as the BMI of the stimulus increased. These results suggest that average DL increased by 0.04 BMI units for every unit increase in Base BMI ($t(257.44) = 10.91$, $p < .001$, 95%CI [0.03 - 0.04]), indicating that the smallest difference people can identify between two BMIs increases as BMI increases. The DL for a BMI that is considered obese (e.g. BMI 35.00, DL = 1.32) is almost double that for an underweight body (e.g. BMI

18.00, DL = 0.69). The positive, linear slope can be seen in Figure 4.2 when plotting the JND for BMI (y-axis) as a function of Base BMI (x-axis).

Figure 4.2

A plot of the average Difference Limen (DL) with standard error bars for the standard stimulus in each of the eight blocks predicted from the mixed-effect linear model.



Abbreviations. DL, Difference Limen, MLM = Mixed-Effect Linear Model.

Weber's fraction was calculated by dividing the predicted JND from the model by the standard stimulus for each of the eight blocks, to determine whether the JND increased at a constant proportion. As expected, Weber's fractions were consistent across blocks: 0.040, 0.039, and 0.038 for blocks 1 - 3, 4 - 6, and 5 - 8, respectively. This consistency suggests that the JND increased linearly, at a constant rate relative to stimulus BMI across the BMI spectrum.

Summary of Results

Overall, these findings demonstrate that body size discrimination, when judging CG bodies that are increasing linearly in BMI, follows a pattern predicted by a well-established perceptual phenomenon (Weber's law). As such, a larger difference between body sizes is needed as body size increases for the difference to be reliability detected, and this increase is linear, demonstrated by the consistency in Weber's fraction across the BMI spectrum. These findings are in line with previous work using CG bodies also calibrated for BMI using the same technique (Cornelissen et al., 2016). This potentially has implications for the development of FRS which use constant BMI spacing between adjacent bodies. In the next study, FRS are created using the JND to determine the spacing between adjacent bodies.

Study 4: Development and Validation of Novel FRS for Assessment of Body Image.

4.6 Method

Ethical approval was gained from the School of Psychology Research and Ethics Committee at the University of Lincoln (Project code: PSY181949).

4.6.1 *Aim*

This study aimed to investigate the reliability and validity of the new theory and data-driven FRS in a sample of women with no current diagnosis/history of an eating disorder, to allow a more in-depth investigation regarding the optimal number of stimuli, whether adjacent stimuli can be discriminated, and whether responses are similar compared to a continuous approach.

4.6.2 *Participants*

Forty-eight females (cis-gender/as assigned at birth) aged 18 - 45 years old (M = 21.81, SD = 4.95), with no current diagnosis/history of an eating disorder were recruited from the University of Lincoln and surrounding areas. The sample was predominantly Caucasian (87.5%). The main methods of recruitment were social media advertisements, word-of-mouth and the recruitment of undergraduate psychology students in return for course credits. Forty-four of these participants also completed the retest two-three days later (91.67% retention rate).

4.6.3 *Materials*

Discrete JND FRS. Two discrete FRS were created using the CG stimuli and results from Study 3. Using the mixed-effect linear model, the JND at different BMI values was calculated using the coefficient and intercept values:

$$JND = 0.0366 * BMI + 0.0561$$

$$(JND = \text{coefficient multiplier} * BMI + \text{intercept})$$

This equation was used to calculate adjacent steps from the starting point of 15 BMI units, which was the lowest BMI stimulus in Study 3. The JND was added to the BMI value to determine the next body in the scale, and once determined, the values were rounded to the nearest 0.25 value to correspond with the rendered stimulus. Based on previous literature, it was decided to employ two discrete FRS to investigate the optimal number of images. Some researchers argue for large scales with small steps between adjacent bodies (e.g. Gardner et al., 1998; Gardner et al., 1999), whereas other researchers suggest seven plus or minus two is optimal (Ambrosi-Randić et al., 2005), so these factors were considered during scale development. The JND was multiplied by different values to create different spacing options, with the spacing between adjacent bodies becoming larger as BMI increased. The final scales were based on doubling the JND, resulting in a scale with 15 images and quadrupling the JND, resulting in a smaller scale with nine images. Examples of each discrete scale can be found in Appendix E.

Fifteen-item FRS (FRS-15). The FRS-15 was created using the JND multiplied by two, resulting in a scale with 15 body images ranging from 15.00 - 43.00 BMI units. In Table 4.3 the BMI value and WHO BMI category of each stimulus used in the scale is presented.

Table 4.3

The BMI value and category of each stimulus in the FRS-15.

Body	BMI	BMI Category
	15.00	
	16.25	Underweight
	17.50	
	19.00	
	20.50	Normal weight
	22.00	
	23.75	
	25.50	
	27.50	Overweight
	29.75	
	32.00	Obese
	34.50	
	37.00	Obese Class II
	40.00	Obese Class III
	43.00	

Nine-item FRS (FRS-9). The FRS-9 was created using the JND multiplied by four, resulting in a scale with nine body images ranging from 15.00 - 40.00 BMI units. In Table 4.4 the BMI value and WHO BMI category of each stimulus used in the scale is presented.

Table 4.4

The BMI value and category of each stimulus in the FRS-9.

Body	BMI	BMI Category
	15.00	Underweight

Body	BMI	BMI Category
	17.50	
	20.00	Normal weight
	22.75	
	25.75	Overweight
	29.00	
	32.50	Obese I
	36.25	Obese Class II
	40.00	Obese Class III

For both scales, stimuli were printed in colour on separate pieces of laminated card (8 x 6 inches). Images were displayed randomly on a desk to prevent memory and procedural effects affecting responses and test-retest reliability (Gardner et al., 1999). Random presentation of FRS does not appear to significantly affect body size estimations (perceived current, ideal or BD) or test-retest reliability (Duncan et al., 2005).

Interactive FRS. An interactive interface was created in MATLAB (Version 2018a; The MathWorks Inc., 2018) using the full range of CG stimuli at every 0.25 BMI units, resulting in a total of 120 rendered body images ranging from 14.25 - 44.00 BMI units. Using the 'method of adjustment' technique (see Cornelissen et al., 2017), participants could scroll through the whole range of stimuli using arrows keys on the keyboard, simulating increases and decreases in BMI. The direction of change produced by the arrow keys was randomised to control for directional preferences/biases. Responses were indicated by pressing the space button to select the body that best represented either their perceived current or ideal size/shape. To avoid anchoring and order effects each body estimation was completed twice from randomly generated starting points and the order was counterbalanced across participants. The average of the two responses was used for data analysis, calculated by averaging the BMI values of the two selected bodies for each estimation.

Psychometrics. The psychometric measures outlined in Section 2.2, Chapter 2 were used to assess body concerns, ideal internalisation, eating disorder psychopathology, self-esteem and depression. For BSQ, EDE-Q, RSES, BDI, SATAQ-4 Thin Ideal Internalisation, and SATAQ-4 Athletic Ideal Internalisation, Cronbach's alpha was .96, .97, .90, .88, .75, and .88, respectively.

Body Measurements. Estimates of body composition and BMI were taken using the Tanita BIA scale, standing height using a stadiometer and circumference measurements using a tape measure (see Section 2.1, Chapter 2).

4.7 Procedure

In the first session, all participants completed tasks using the three FRS (15-item, 9-item, and interactive) after providing informed consent. Using the discrete FRS, participants were asked to order the body images in ascending order from the smallest to the largest body size, select their perceived current (most like their current body size) and ideal body size (most like their ideal body size). When using the interactive FRS, participants were asked to select their perceived current and ideal body size using a method of adjustment paradigm. The order of tasks and FRS presentation were randomised. Next, participants answered demographic questions (age, sex, ethnicity, and current diagnosis/history of an eating disorder), completed the psychometric measures using a Qualtrics form, and had their body measurements taken.

Two-to-three days after the first session, participants completed the FRS tasks again in a randomised order before being debriefed. The whole procedure took approximately 45 minutes (30 minutes for session 1 and 15 minutes for session 2).

4.8 Data Analysis

Analyses were conducted using IBM SPSS 26. Participant's responses on each FRS for each session were coded as the BMI value associated with their stimulus selection. These BMI values were then used for analyses.

In addition to perceived current and ideal body selections, two new body estimation variables were calculated, resulting in four body estimation variables used for analyses. Body Image Distortion (BID; the difference between the participant's perceived and actual body size) was calculated by subtracting actual BMI from perceived current BMI for each FRS, in each session. A negative value indicates underestimation, 0 indicates complete accuracy, and a positive value indicates overestimation of body size. Perceptual Body Dissatisfaction (BD; the difference between the participant's ideal and perceived body size) was calculated by subtracting perceived current BMI from ideal BMI for each FRS, in each session. A negative value indicates a desire for an ideal BMI smaller than perceived current, 0 indicates no difference, and a positive value indicates a desire for an ideal BMI larger than perceived current.

Responses obtained from the discrete FRS provided ordinal data and were analysed using non-parametric statistical methods. Responses obtained from the interactive body scale, psychometric measures, and BID/BD estimations for each FRS were inspected for normality via visual inspection of histograms and Shapiro-Wilk tests for each variable. Shapiro-Wilk tests revealed that only SATAQ-4 thin and athletic ideal internalisation scores were normally distributed ($p > .05$). All other variables were non-normal and so all data were analysed using non-parametric methods.

4.9 Results

4.9.1 *Participant Characteristics*

Table 4.5 presents participant characteristics, including age, BMI, and body composition (body fat percentage, fat mass in kg, fat-free mass, total muscle mass, and WHR). When looking at the sample distribution according to BMI category, 6.30% were underweight, 58.30% were normal weight, 20.80% were overweight, and 14.60% were obese. There was a 91.67% retest rate (n = 44), and no statistically significant differences were found between any of the sample characteristics, determined using Mann-Whitney Tests (all *p*s > .05).

Table 4.5

Participant characteristics (mean, standard deviation, minimum, and maximum) in each session.

	Session 1 (n = 48)				Session 2 (n = 44)				
Participant Characteristic	*M*	SD	Min	Max	*M*	SD	Min	Max	*p*
Age	21.81	4.95	19.00	40.00	21.50	4.72	19.00	40.00	> .05
BMI	24.34	5.22	16.90	39.59	23.84	4.82	16.90	36.14	> .05
Fat %	29.46	7.43	15.00	47.70	28.71	7.04	15.00	44.10	> .05
Fat Mass	20.81	9.78	6.90	50.20	19.77	8.95	6.90	45.50	> .05
FFM	46.64	5.87	35.10	59.00	46.21	5.84	35.10	59.00	> .05
Muscle Mass	44.27	5.58	33.30	56.00	43.86	5.55	33.30	56.00	> .05
WHR	0.76	0.05	0.68	0.91	0.76	0.05	0.68	0.91	> .05

Abbreviations. Fat %, body fat percentage; FFM, Fat-Free Mass; WHR, Waist-to-Hip Ratio

4.9.2 *Psychometric Measures*

Descriptive statistics for psychometric data obtained in session 1 (n = 48) is presented in Table 4.6. Details regarding relationships between psychometric measures and body measurements can be found in Appendix E. In Chapter 3, a Principal Component Analysis was employed to determine latent factor/s, but this was not conducted here as the relationships between body estimations and specific measures of attitudinal and psychological concerns were important to identify, for validation purposes. Using latent factors may mean specific relationships between the body estimations and psychological/attitudinal concerns are missed. Moreover, analyses for scale validity require focusing on specific variables and scales/subscales, which would not be possible when using latent factor/s.

Table 4.6

Descriptive statistics (mean, standard deviation, minimum, and maximum) for the psychometric measures.

Psychometrics (n = 48)	*M*	SD	Min	Max
EDE-Q Dietary Restraint	1.50	1.47	0.00	5.40
EDE-Q Eating Concerns	1.22	1.41	0.00	4.80
EDE-Q Shape Concerns	2.54	1.81	0.00	6.00
EDE-Q Weight Concerns	2.10	1.75	0.00	6.00
EDE-Q Global	1.84	1.50	0.00	5.55
RSES Total	17.38	5.23	7.00	30.00
BDI Total	11.38	8.14	0.00	31.00
BSQ Total	44.12	19.08	16.00	92.00
Thin Ideal Internalisation	3.06	0.85	1.00	5.60
Athletic Ideal Internalisation	2.59	1.03	1.00	5.00

4.9.3 *Body Scale Estimations*

Descriptive statistics for each FRS and session are presented in Table 4.7. Participants were fairly accurate at estimating their body size – they were within 1.30 BMI units, on average, across all scales and sessions. The biggest discrepancy was in session 2 using the FRS-15. Participants never chose the most extreme body sizes for their perceived current and ideal selections, on all three FRS. A narrow range of ideal body sizes were selected; only eight of the possible body sizes were selected in the FRS-15 and four in the FRS-9. On average, the ideal body size was around 20.38 BMI units which is at the low end of the normal BMI classification. The largest selected ideal body size was 27.50 using FRS-15, and no woman chose an ideal body size that would be considered obese. In corroboration with other research, women typically desired an ideal body size that was smaller than their own perceived body size (BD), on average by around 4.20 BMI units (see Table 4.7).

Table 4.7

Descriptive statistics (mean, standard deviation, and range) for the interactive, FRS-15, and FRS-9 scales in each session.

	Session 1 (n = 48)			Session 2 (n = 44)		
	M	SD	Range	*M*	SD	Range
			Interactive			
Current	23.71	4.53	17.00 - 36.88	24.07	4.70	18.13 - 38.13
Ideal	19.65	2.19	15.38 - 25.63	20.26	2.46	15.88 - 26.38
BID	-0.63	2.80	-9.22 - 5.97	0.23	3.23	-7.03 - 11.65
BD	-4.06	3.55	-17.12 - 2.63	-3.81	3.56	-16.50 - 2.38
			FRS-15			
Current	25.04	5.09	17.50 - 37.00	25.13	5.00	19.00 - 40.00
Ideal	20.53	2.42	16.25 - 27.50	20.73	2.30	17.50 - 27.50
BID	0.70	2.70	-5.28 - 10.02	1.29	2.95	-5.28 - 12.52
BD	-4.51	4.35	-16.50 - 4.50	-4.39	4.36	-19.50 - 3.00
			FRS-9			
Current	24.84	4.96	17.50 - 36.25	24.72	4.85	17.50 - 36.25
Ideal	20.31	2.37	17.50 - 25.75	20.81	2.22	17.50 - 25.75
BID	0.50	2.95	-6.03 - 10.52	0.88	2.78	-3.15 - 10.52
BD	-4.53	3.75	-16.25 - 2.75	-3.91	3.92	-16.25 - 2.75

Scale Agreement. Spearman's Rank correlations were used to look at the relationship between body estimation variables (perceived current, ideal, BID, and BD) from each FRS (in session 1, n =48) to look at consistency across scales. There were significant, positive correlations between body estimation variables on each of the scales, suggesting good consistency across scales. Table 4.8 displays Spearman's Rank coefficients and significance values.

Table 4.8

The relationship between body estimation variables on each of the scales (session 1, n = 48).

Body Estimation	Scale	Interactive	FRS-15
Current	FRS-15	.88***	
	FRS-9	.87***	.94***
Ideal	FRS-15	.62***	
	FRS-9	.60***	.75***
BID	FRS-15	.63***	
	FRS-9	.72***	.71***
BD	FRS-15	.76***	
	FRS-9	.78***	.85***

* $p < .05$, ** $p <.005$, ***, $p < .001$.

Construct Validity.

Convergent Validity. Convergent validity for each of the FRS was assessed by looking at the relationship between perceived current estimations (session 1, n = 48), actual BMI, and total fat mass using Spearman's Rank correlations. The results showed significant positive correlations between perceived current and actual BMI on all three FRS (interactive, $r_s = .74$, $p < .001$; FRS-15, $r_s = .81$, $p < .001$; FRS-9, $r_s = .76$, $p < .001$). Similarly, perceived current body size was positively significantly correlated with total fat mass (interactive, $r_s = .75$, $p < .001$; FRS-15, $r_s = .80$, $p < .001$; FRS-9, $r_s = .75$, $p <.001$). There were no significant differences between perceived current BMI and actual BMI on any of the FRS, determined using Wilcoxon Signed-Rank tests (interactive, Z = -1.71, $p = .087$; FRS-15, Z = -1.46, $p = .145$; FRS-9, Z = -.97, $p = .330$). Descriptive statistics of the mean perceived current BMI and the mean difference between actual and perceived current BMI (BID) can be found in Table 4.8. These results indicate that the FRS demonstrate good convergent validity because perceived current estimations were strongly correlated with both BMI and fat mass, and were on average, accurate and not significantly different to actual BMI.

Discrete Scales Perceptual Discrimination. Responses obtained from the ordering tasks were used to investigate perceptual distinguishability between adjacent bodies (i.e. whether the differences between images were identifiable). Using an ordering task like Thompson and Gray (1995), we could compare agreement between participants' positioning of stimuli and the actual (correct) position. The number of errors (incorrectly placed bodies) was calculated for each FRS and session. As they contained different numbers of bodies, the number of errors for each FRS and session are presented in Table 4.9, with the number and proportion of participants.

Using the FRS-15, just over half the participants could correctly order all the stimuli (54.45%), suggesting that around half of the sample were unable to easily identify differences between all bodies. The majority of errors were misplacing two of the bodies (31.36% of participants). Using the FRS-9, almost all participants (95.74%) could correctly order all the stimuli, suggesting good perceptual distinguishability between adjacent stimuli. In the first session, all errors came from misplacing two of the bodies, however, in the second session all errors came from one participant misplacing four of the nine bodies (see Table 4.9). This suggests that the FRS-9 has more perceptually distinguishable spacing between adjacent bodies than the FRS-15.

Table 4.9

The number and proportion of participant's incorrect responses using the discrete scales (FRS-9 and FRS-15), in each session.

	FRS-15		FRS-9	
Incorrect Responses	Session 1 (n = 48)	Session 2 (n = 44)	Session 1 (n = 48)	Session 2 (n = 44)
0	25 (52.08%)	25 (56.82%)	45 (93.75%)	43 (97.73%)
2	14 (29.17%)	15 (34.09%)	3 (6.25%)	0 (0%)
3	3 (6.25%)	0 (0%)	0 (0%)	0 (0%)
4	6 (12.50%)	3 (6.82%)	0 (0%)	1 (2.27%)
8	0 (0%)	1 (2.27%)	0 (0%)	0 (0%)

Note. Numbers indicate the number of participants, followed by the proportion of the sample in parentheses. No participants incorrectly ordered 5, 6, or 7 images and to incorrectly place just 1 body was not possible.

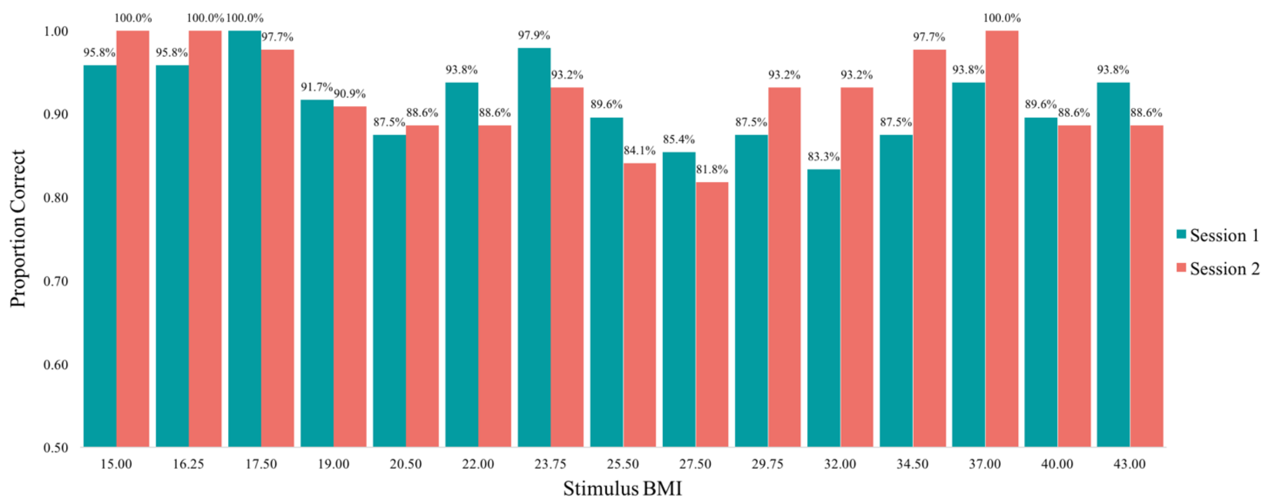
Next, the percentage of correct responses per stimulus was calculated to determine accuracy according to stimulus BMI. This was then averaged across the two sessions to get an estimate of overall accuracy for each stimulus. Stimulus accuracy for each session is presented in Figures 4.3 and 4.4.

In the FRS-15, where there were generally more errors, it was found that the stimuli with the least accuracy (averaged across both sessions) were BMIs 27.50 (83.60%), 25.50 (86.80%), 20.50 (88.10%) and 32.00 (88.30%). The stimuli with BMIs of 27.50 and 25.50 were adjacent stimuli both in the overweight BMI category and were often misplaced with one another (100% of misplacing errors for BMI 25.50 was with 27.50). The stimuli with the highest accuracy were those in the underweight BMI category: 17.50 (98.90%), 16.25 (97.90%), and 15.00 (97.90%). The largest stimulus (43.00 BMI units) was correctly placed 91.20% of the time. See Figure 4.3

for percentage accuracy for each stimulus, at each time point. This suggests that perceptual discriminability is highest at the lower end of the BMI spectrum.

Figure 4.3

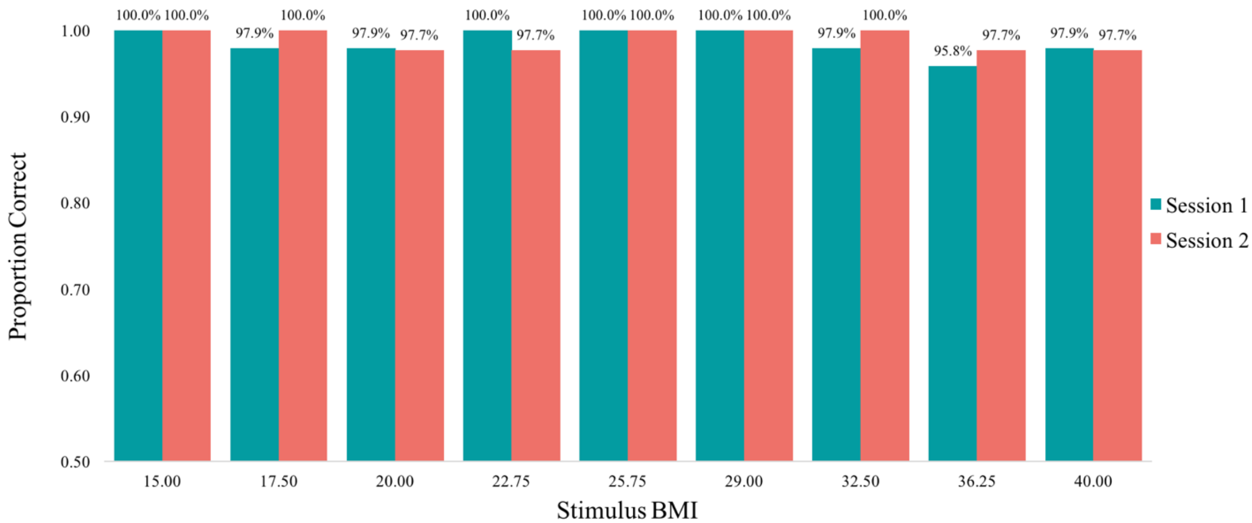
Stimulus discrimination accuracy for FRS-15 (proportion of correct responses, where 1 is 100% accuracy), for each session.



In the FRS-9, there were generally fewer errors than the FRS-15. Using this scale, three stimuli were placed correctly 100% of the time: BMIs 15.00, 25.75, and 29.00. The largest stimulus (40.00 BMI units) was correctly placed 97.80% of the time. Figure 4.4 displays accuracy for each stimulus, at each time point. The high percentage of correct responses indicates good perceptual discrimination between adjacent bodies in this FRS.

Figure 4.4

Stimulus discrimination accuracy for FRS-9 (proportion of correct responses, where 1 is 100% accuracy), for each session.



Concurrent Validity. Concurrent validity was analysed by looking at the relationship between perceptual BD (session 1, n = 48) and attitudinal body image (scores from the psychometric measures related to body image: EDE-Q, BSQ, and SATAQ-4 thin and athletic internalisation scores). Results indicate that all three FRS show good concurrent validity as perceptual BD significantly, negatively correlated with EDE-Q and BSQ scores. This indicates that as disordered eating psychopathology and body concerns increase, there is a larger discrepancy between perceived and ideal body size, in the direction of desiring a smaller ideal body size. Only BD values from the FRS-15 showed a significant, negative correlation with thin ideal internalisation. Perceptual BD was not related to athletic ideal internalisation (i.e. the drive for a more muscular physique) which indicates that these FRS capture concerns with body weight, fat, and shape. Spearman's Rank coefficients and significance levels are presented in

Table 4.10. Correlations with EDE-Q subscales are not presented, however, like the global score, the correlations for each subscale were significant and negative ($r_s > -.41$, $p < .05$).

Table 4.10

The relationship between attitudinal body image and the discrepancy between perceived and ideal body size, for each scale (session 1, n = 48).

Scale	EDE-Q Global	BSQ	Thin Ideal Internalisation	Athletic Ideal Internalisation
Interactive BD	-.49***	-.37**	-.24	.07
FRS-15 BD	-.47**	-.37**	-.32*	-.04
FRS-9 BD	-.45**	-.34*	-.21	.03

*** $p < .001$, ** $p < .005$, * $p < .05$

Spearman's Rank partial correlations were run for the relationship between perceptual BD and EDE-Q Global/BSQ scores, to control for BMI. The associations between BD and EDE-Q Global remained significant for each FRS (interactive, $r_s = -.37$, $p = .011$; FRS-15, $r_s = -.32$, $p = .026$; FRS-9, $r_s = -.30$, $p = .044$). For the BSQ, the associations were no longer significant when controlling for actual BMI (interactive, $r_s = -.25$, $p = .087$; FRS-15, $r_s = -.22$, $p = .133$; FRS-9, $r_s = -.18$, $p = .237$).

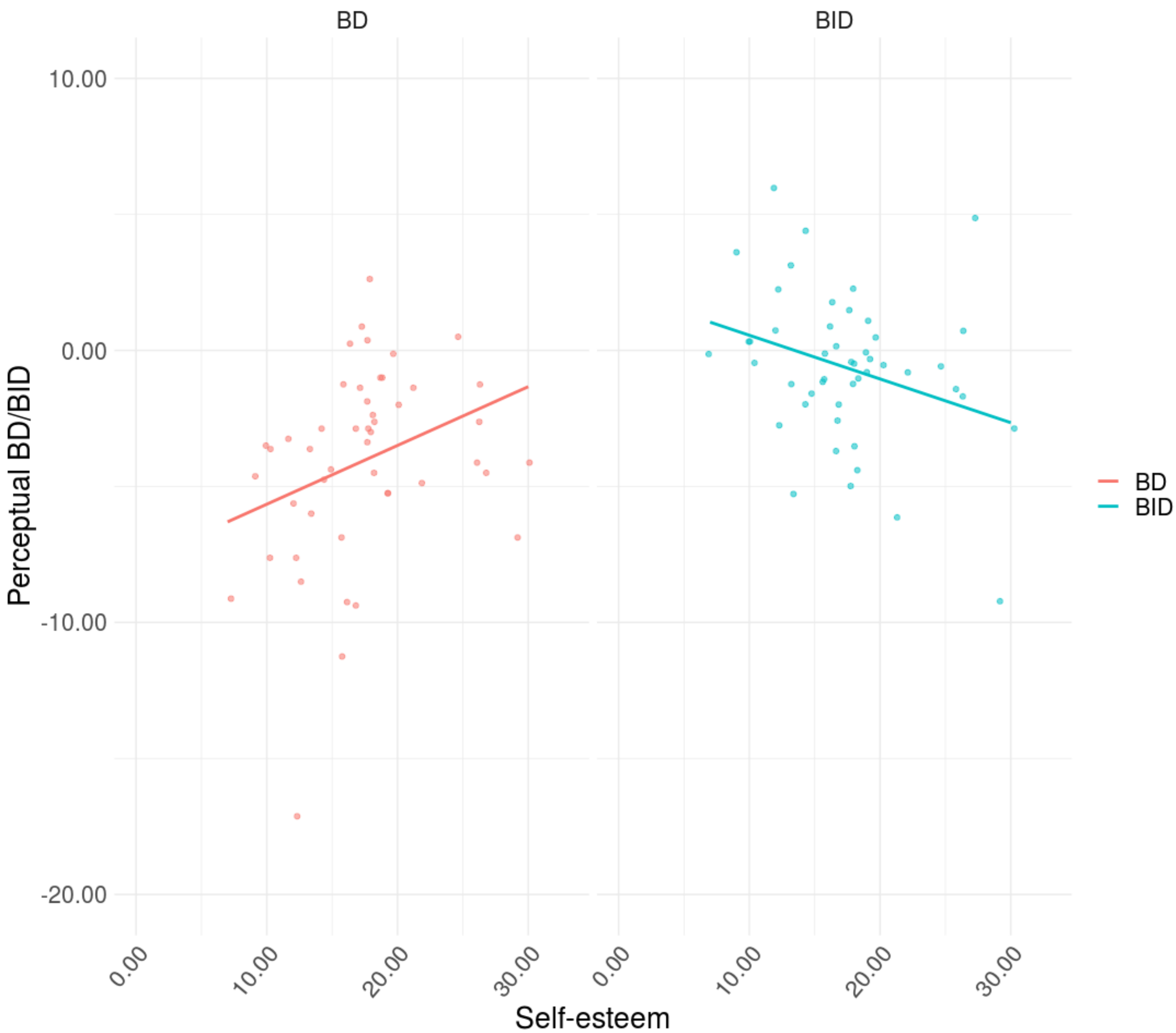
Ideal body size selections using the FRS-15 (session 1, n = 48) were also significantly, negatively correlated with EDE-Q shape concerns ($r_s = -.32$, $p = .025$), BSQ ($r_s = -.31$, $p = .034$), and thin ideal internalisation scores ($r_s = -.32$, $p = .026$). Those with higher internalisation of a thin ideal and concerns with body shape/weight typically desired a thinner body ideal. Ideal body size selections for the interactive and FRS-9 scales did not significantly correlate with any of the psychometric measures. Spearman's Rank partial correlations were run to control for BMI. There were significant, negative associations between EDE-Q Global (interactive, $r_s = -.35$, $p = .017$;

FRS-15; r_s = -.45, p = .002; FRS-9, r_s = -.32, p = .026) and for BSQ (interactive, r_s = -.30, p = .044; FRS-15; $r_s(45)$ = -.46, p = .001; FRS-9, $r_s(45)$ = -.39, p = .007). These results indicate that a smaller ideal body size is significantly associated with increased disordered eating psychopathology and body concerns, when controlling for the persons actual BMI, which was not evident when BMI was not controlled for.

Discriminant Validity. Discriminant validity was analysed by looking at the relationship between perceptual BD/BID measured using each of the FRS in session 1 (n = 48) and general psychological wellbeing from the psychometric measures (BDI and RSES). Only perceptual BD from the interactive scale significantly, positively correlated with RSES scores (r_s = .40, p = .005), indicating a larger, negative discrepancy between ideal and perceived BMI (desiring a smaller body size than perceived) was associated with a decrease in self-esteem. Similarly, BID from the interactive scale significantly, positively correlated with RSES scores (r_s = -.30, p = .039), indicating an association between decreased self-esteem and body size overestimation. See Figure 4.5.

Figure 4.5

The relationship between self-esteem and the discrepancy between perceived and actual BMI (BID) and the discrepancy between perceived and ideal BMI (BD) on the interactive scale.



4.9.4 *Test-retest Reliability*

To examine test-retest reliability, associations between body estimation variables in session 1 and session 2 were calculated using Spearman's Rank correlations (n = 44). The results showed strong, positive correlations between estimations in session 1 and session 2 for all FRS (see Table 4.11 for coefficients and significance values).

Table 4.11

The relationship between body estimation variables in session 1 and session 2 for each scale.

Body estimation	Interactive (n = 44)	FRS-15 (n = 44)	FRS-9 (n = 44)
Current	.79***	.94***	.87***
Ideal	.79***	.78***	.69***
BID	.69***	.69***	.60***
BD	.65***	.88 ***	.84***

*** $p < .001$, ** $p < .005$, * $p < .05$

Additionally, two-way random intraclass correlations for absolute consistency were conducted for each body estimation variable, for each FRS. All Intraclass Correlation Coefficients (ICCs) were statistically significant, indicating good absolute consistency between values in session 1 and 2 ($p < .001$). All ICC values, except for interactive BID, met or exceeded Nunnally's (1978) 0.70 criterion for acceptable test-retest reliability and many met the more stringent 0.80 criterion (Carmines, 1990). Wilcoxon Signed-Rank Tests were used to compare body estimations between session 1 and 2. All ICC values and differences between sessions are displayed in Table 4.12.

Table 4.12

Summary of test-retest reliability: means, standard deviations, Intraclass Correlation Coefficients, 95% confidence intervals, and statistical differences between session 1 and session 2, for each body estimation variable and each scale.

		Session 1 (n = 44)	Session 2 (n = 44)			Wilcoxon Signed-Rank Test
Scale	Body Estimation	*M* (SD)	*M* (SD)	ICC	95% CIs	*Z*
Interactive	Current	23.37 (4.49)	24.07 (4.70)	.86***	.75- .92	-1.71
	Ideal	19.56 (2.21)	20.26 (2.46)	.87***	.77 - .93	-3.41***
	BID	-0.47 (2.61)	0.23 (3.23)	.65***	.43 - .79	-1.71
	BD	-3.81 (3.55)	-3.81 (3.56)	.75***	.58 - .86	-0.25
FRS-15	Current	24.58 (4.87)	25.13 (5.00)	.94***	.89 - .97	-1.79
	Ideal	20.38 (2.17)	20.73 (2.30)	.77***	.61 - .87	-1.29
	BID	0.74 (2.76)	1.29 (2.95)	.82**	.69 - .90	-1.79
	BD	-4.20 (4.35)	-4.39 (4.36)	.88***	.78 - .93	-0.42
FRS-9	Current	24.36 (4.67)	24.72 (4.85)	.90***	.82 - .94	-1.00
	Ideal	20.21 (2.33)	20.81 (2.22)	.76***	.59 - .86	-2.13*
	BID	0.52 (3.00)	0.88 (2.78)	.71***	.53 - .83	-1.00
	BD	-4.15 (3.52)	-3.91 (3.92)	.83***	.71 - .90	-0.49

*** $p < .001$, ** $p < .005$, * $p < .05$

4.9.5 *The Relationship Between Body Estimates and Actual Body Size*

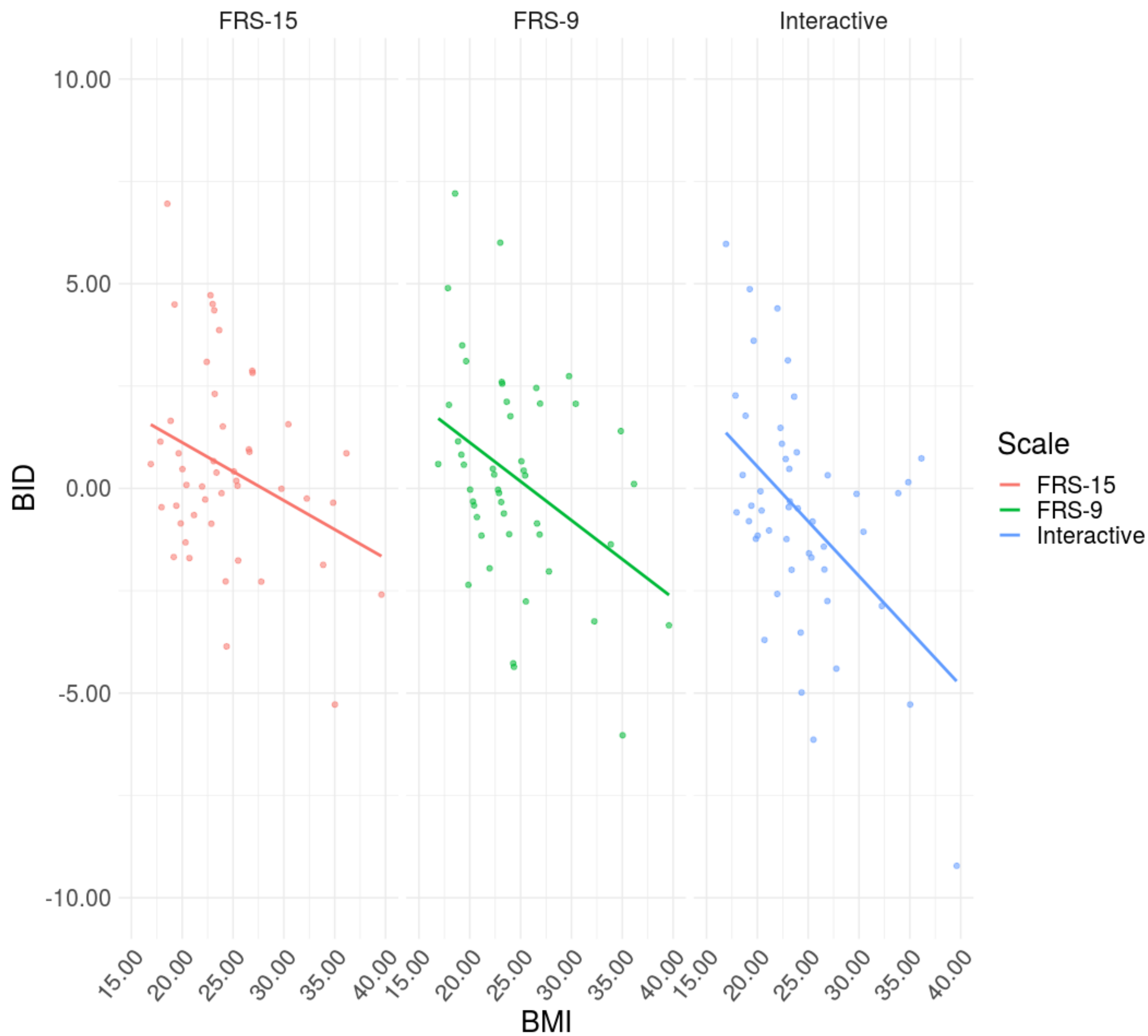
As reported earlier, estimates of perceived BMI were significantly positively correlated with actual BMI and fat mass ($r_s > .74$, $p < .001$). Significant positive correlations were also found between ideal BMI selections and actual body size (session 1, n = 48): BMI (interactive, $r_s = .59$, $p < .001$; FRS-15, $r_s = .33$, $p = .020$; FRS-9, $r_s = .49$, $p < .001$), and fat mass (interactive, r_s

= .56, p < .001; FRS-15, r_s = .34, p = .019; FRS-9, r_s = .47, p = .001), indicating that ideal body size increases as actual BMI/fat mass increases.

There were also significant, negative associations between BID and actual BMI (session 1, n = 48) using the interactive (r_s = -.45, p < .001) and FRS-9 (r_s = -.35, p = .015) scales. This is demonstrated in Figure 4.6. This is in line with predictions of body size estimation accuracy following contraction bias and previous research suggesting that as body size increases, people tend to underestimate whereas when body size decreases there is less underestimation and a trend towards overestimation (Cornelissen et al., 2015).

Figure 4.6

The relationship between the discrepancy between perceived current and actual BMI (BID) and actual BMI, on each scale.

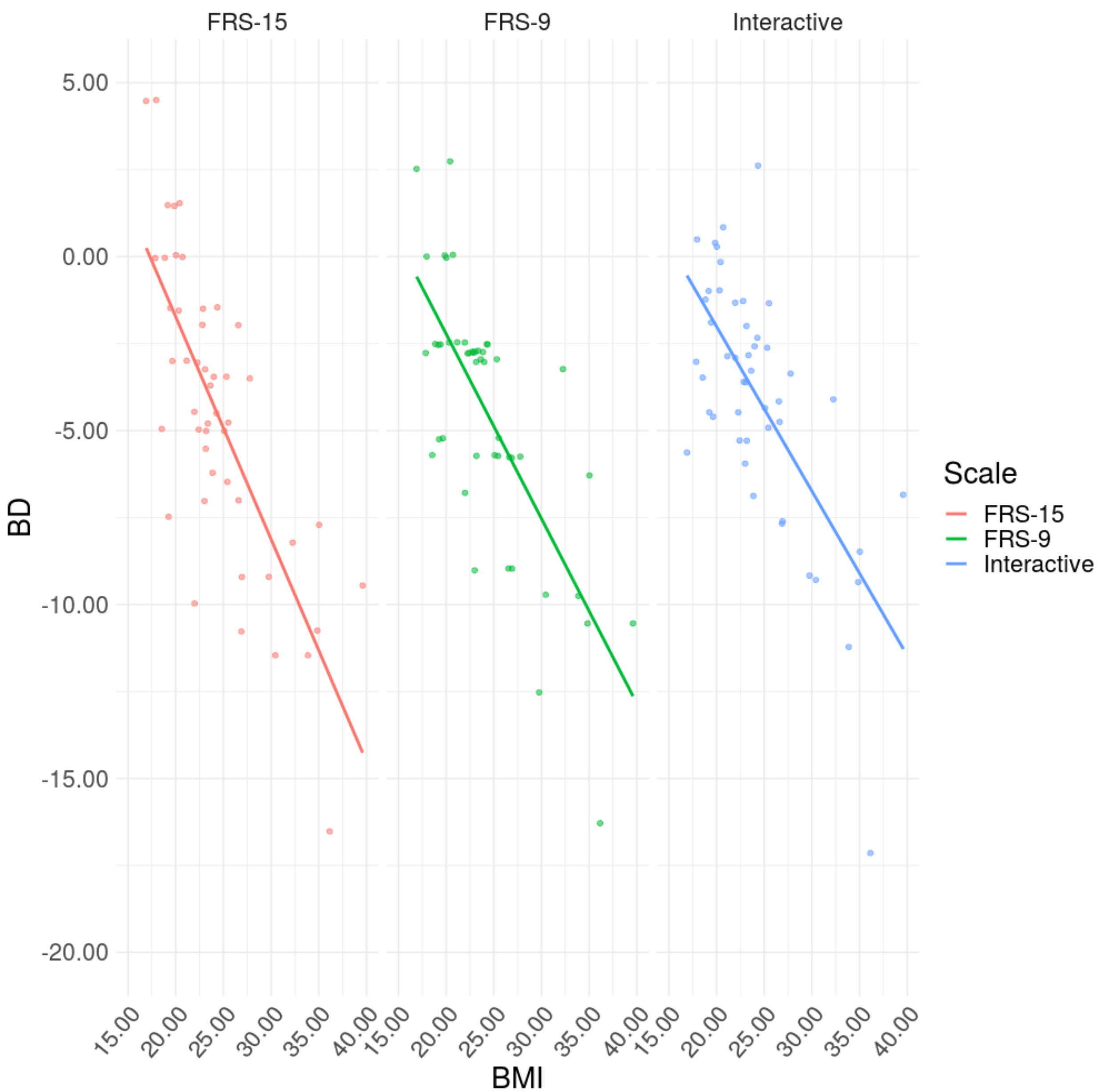


Significant negative associations were found between perceptual BD and BMI (session 1, n = 48) for all three FRS (interactive, $r_s = -.59$, $p < .001$; FRS-15, $r_s = -.74$, $p < .001$; FRS-9, $r_s = -.73$, $p < .001$). This relationship implies that as BMI increases, there is a larger discrepancy between perceived and ideal body size, becoming more negative, such that the person's ideal

BMI is smaller than their perceived current BMI. As BMI decreases, the discrepancy becomes smaller or positive, such that the person's ideal BMI is the same or higher than their perceived current BMI (see Figure 4.7).

Figure 4.7

The relationship between the discrepancy between ideal and perceived current BMI (BD) and actual BMI, on each scale.



4.10 Discussion

Using a series of CG female bodies varying in BMI and a computerised 2AFC task, the smallest differences in BMI that a participant could reliably detect across the BMI spectrum were identified. As predicted, the smallest difference increased as BMI increased. For example, these data suggest that a body of 18.00 BMI units would require a 0.69 BMI unit change for a difference to be detected, whereas a body of 35.00 BMI units would require around double the amount of change (1.32 BMI units). These results are similar to previous findings by Cornelissen et al. (2016), substantiating evidence of Weber's law as a robust perceptual phenomenon applying to sensitivity in BMI change when using standardised CG bodies increasing linearly in BMI. These findings were then used to develop novel discrete FRS with spacing that reflected this perceptual phenomenon so that the difference in BMI between adjacent bodies increased as BMI increased. Two FRS were developed; one larger scale (FRS-15) with smaller differences between adjacent bodies, and one smaller scale (FRS-9) with larger differences between adjacent bodies. A third, continuous FRS was created to investigate responses that were not limited by discrete options.

Overall, good reliability and validity were demonstrated for each of the FRS. Estimates of current body size were accurate, compared to actual BMI on each of the FRS, and estimates of perceptual BD were significantly associated with BD measured using psychometric measures, indicating good construct validity. Similar to previous research we found that women typically desired an ideal body size smaller than their own (e.g. Crossley et al., 2012; MacNeill & Best, 2015; Nissen & Holm, 2015) and that both ideal body size and the discrepancy between perceived current and ideal body size were related to BMI (again, consistent with previous research; Tovée et al., 2003). The discrete scales (FRS-15 and -9) were designed based on JND data, to produce FRS with perceptually distinguishable BMI differences between adjacent bodies, while this was demonstrated for the 9-item scale, producing similar findings to Thompson and Gray (1995) and Mutale et al. (2016), it was not the case for the 15-item scale. Nevertheless, both scales produced similar body estimation responses, which suggests that the ability to discriminate between adjacent bodies may not necessarily impact the measurement of perceptual body image using FRS.

The benefits of using a continuous FRS were explored, but this study did not find any clear benefit to using this approach instead of a discrete FRS (i.e. the interactive scale did not result in more accurate responses). There was high agreement between the continuous and discrete FRS. Although, BID and BD on the interactive scale were associated with self-esteem, whereas the other scales were not. Considering these findings, the purpose of using a FRS should be determined before selecting the appropriate scale for use. For example, the smaller scale (FRS-9) may be beneficial in healthcare/clinical settings, online research, and research where space may be limited, due to the reduced number of stimuli. If the research is focusing on longitudinal or repeated measurements, the FRS-15 may be useful as it demonstrated the greatest test-retest reliability and the highest consistency between selections in each session. The interactive scale allows for more precise measurements, containing 120 bodies spaced 0.25 BMI units apart, and is still a quick and easy tool when a computer is available, rendering it a useful method for research settings where precise judgements are necessary. This may also be a useful tool for research using method of adjustment techniques and those interested in more general body size judgements such as attractiveness, health, BMI, and weight (e.g. the categorical boundary between normal and overweight).

In this research, we chose to use CG stimuli calibrated for BMI for the aforementioned benefits (e.g. standardisation of pose/body proportions, photorealistic skin texture, and ecologically valid body size/shape manipulations). Only a few FRS have been created using CG stimuli (e.g. Moussally, Grynberg et al., 2017; Mutale et al., 2016; Talbot et al., 2019) and to the best of our knowledge, none have been created that use data-driven approaches to spacing. Recent research suggests that CG body stimuli may result in poorer discriminability and larger errors when making body size judgements (Alexi et al., 2019). The authors suggest that despite calibration for BMI, CG stimuli may not be realistic at weight extremes, which may be a factor to consider when interpreting the findings from this research. However, unlike Alexi et al. (2019), the CG stimuli in this research used linear changes in BMI (calibrated based on the average body shape of a woman in the UK), maintained a standard pose, and were photorealistic. On the other hand, research using CG stimuli calibrated in the same way suggests these bodies are judged similarly to photographs of real bodies (Cornelissen et al., 2016; Tovée et al., 2012). Similarities in visual attention between CG stimuli and photographs have also been found (Leehr et al., 2018). This study demonstrated that women were fairly accurate at estimating their body size (with deviations following that predicted by a contraction bias explanation – overestimation at low BMIs and underestimation at high BMIs. Ideal body size estimates were at the low end of the normal BMI range, as expected based on previous research (Tovée et al., 2003; Tovée & Cornelissen, 2001; Tovée et al., 2002; Wardle & Johnson, 2002). There was poorer discriminability/more errors when using double the JND to space adjacent bodies (FRS-15), but discrimination when using quadruple the JND (FRS-9) was good, determined using an ordering task. Together these findings demonstrate that these stimuli accurately capture BMI and present similar findings to research using photographs and self-report. Further exploration of the similarities/differences between these CG stimuli and real bodies may be worthwhile. Future research may also seek to develop a further understanding of perceptual discriminability for the CG stimuli in these FRS, for example, using a 2AFC like the one in Study 3 and used by Mutale et al. (2016). In addition, prospective work may benefit from using eye-tracking techniques to identify which areas of the body people are attending to during perceptual tasks on the FRS, particularly if CG stimuli is to be used more frequently in subsequent research.

The findings from this validation study suggest that these data-driven FRS show good test-retest reliability, two-to-three days after initial testing. Some previous research has used longer retest intervals ranging between one and three weeks (e.g. Arkenau et al., 2020; Gardner et al., 2009; Talbot et al., 2018). Test-retest reliability for these FRS over a longer time period may be assessed. Additionally, these FRS were created to capture a wide range of BMIs (from underweight to obesity class III), however, the sample used for this validation study mostly consisted of young, university-aged women, with over half of the sample in the normal BMI range (58.30%). Since this research found relationships between participants BID/BD and actual BMI, the psychometric properties of these FRS should be investigated in larger samples of underweight and overweight/obese women. Expanding the scope of the sample and conducting further validation work to explore the psychometric properties of these FRS in a broader sample of women would be beneficial, particularly if they are to be used in healthcare/clinical settings and future research.

Furthermore, considerations should be made regarding stimulus generalisability. For this research, a photorealistic Caucasian CG model was used, which was calibrated based on UK body data from Caucasian adults aged 18 - 45 (average age, 29). Some researchers argue for complete removal of appearance-related features e.g. facial features, ethnicity, clothing etc. (Gardner et al., 1999), whereas others argue for increased ecological validity when using standardised CG bodies including appearance-related features (Mutale et al., 2016). We chose the latter for the benefits of ecological validity and realism. However, this potentially limits the applicability of these FRS in cross-cultural research, non-Caucasian samples, and for use with older adults. Using bodies with a Caucasian skin texture may reduce identification of non-Caucasian adults with the images. One way to combat this issue may be to present the stimuli in grayscale (e.g. Swami et al., 2015; Swami et al., 2012). Nevertheless, issues with generalisability still remain due to differences in patterns of weight distribution and fat deposition between ethnic groups (Shiwaku et al., 2004; Wang et al., 1994), for example, South Asian adults tend to have increased fat deposition around the trunk and less skeletal muscle mass overall (Misra & Khurana, 2011). Similarly, body shape changes with age (Wells et al., 2008), particularly in women where older women have greater upper and central body girths (e.g. waist and arm widths) than younger women (Wells et al., 2007). This may potentially impede body size estimation accuracy when using these FRS across different age/ethnic groups as the stimuli do not represent variances in weight distribution and may affect the participant's ability to relate to and identify with the body shape of the stimuli. Thus, in future, the development of ethnically diverse and age-appropriate stimuli must be considered if these FRS are to be used more broadly, to ensure they are suitable for the sample in question. One way to do this may be to use 3D scanning techniques and accompanying body data to create FRS which use a statistical mapping between 3D shape and BMI, using a large sample of volunteers from different age and ethnic groups.

In conclusion, the JND that can be identified between body sizes across the BMI spectrum has been calculated using a set of standardised CG stimuli. Comparable with previous research the JND increases as BMI increases, suggesting that CG stimuli are prone to a common visual bias (Weber's law). These findings were used to develop two novel discrete FRS, alongside a continuous scale, which all demonstrated good psychometric properties. These FRS may be useful tools, used together or separately, for fast, reliable, and valid estimates of perceptual body image, allowing direct comparisons to the participant's own BMI.

Chapter 5: (Study 5): Accuracy of BMI Categorisations and Attitudes towards Weight Loss across the BMI Spectrum, using 3D Body Shapes Presented in 2D

5.1 Introduction

A substantial amount of empirical research has demonstrated evidence that adults are often poor at visually estimating their own BMI, as discussed in more depth in Section 1.4, Chapter 1. For example, those with lower BMIs tend to overestimate their body size and those with higher BMIs underestimate their body size, suggesting that there is a relationship between body size estimation accuracy and the persons own BMI using different methods, including visual estimations and BMI/weight status categorical labels (e.g. Cornelissen et al., 2015; Cornelissen et al., 2013; Gregory et al., 2008; Truesdale & Stevens, 2008; Vartanian & Germeroth, 2011). Other research suggests that overweight/obese women were more likely to accurately perceive their weight status than men (although around a quarter of the women still underestimated their weight status), yet normal/underweight women were more likely to overestimate their weight status than men (Chang & Christakis, 2003; Kuchler & Variyam, 2003; Nissen & Holm, 2015). Evidence suggests that these patterns of findings extend to judgements made about other adult bodies, where both male and female overweight/obese bodies are often underestimated and perceived as lower in BMI than they actually are (e.g. Cornelissen et al., 2016; Gledhill et al., 2019; Oldham & Robinson, 2016, 2017). When applied in healthcare/clinical settings, a variety of studies have found inaccuracies in the visual estimation of patient weight status by a range of healthcare professionals (Ahern et al., 2012; Robinson et al., 2014; Yoong et al., 2013). These findings suggest that visual perception of BMI is often inaccurate, with overestimation occurring at the lower end of the BMI spectrum and underestimation at the higher end of the BMI spectrum.

5.1.1 *Perceptual Explanations*

One explanation accounting for underestimation of overweight/obesity is termed 'the Visual Normalisation Theory' (Robinson, 2017), which proposes that increases in the proportion of people categorised as overweight/obese has resulted in an upward shift and recalibration of what is considered a normal body size, subsequently resulting in those body sizes being under-estimated and –detected. This is a norm-based theory where only body sizes above the perceived norm would be considered overweight or obese (Oldham & Robinson, 2017). Another possible, albeit not mutually exclusive, explanation is a perceptual phenomenon termed 'contraction bias' (Poulton, 1989), which proposes that an individual uses a standard reference for body size when making visual estimates, based on all the bodies seen and influenced by those most familiar/seen regularly (Rhodes et al., 2013; Winkler & Rhodes, 2005). Body size estimates are most accurate when the size is close to the standard reference, but as the body size deviates from the standard reference the estimates become increasingly inaccurate. Therefore, systematic inaccuracies in body size judgements may arise from a bias towards the standard reference, which has been demonstrated using a variety of body size judgement tasks (e.g. Alexi et al., 2018; Cornelissen et al., 2015; Gledhill et al., 2019). This bias in judgement may then explain inaccuracies across the BMI spectrum, in that bodies below the standard reference are overestimated and bodies above are underestimated, with the magnitude of error increasing with deviations from the standard reference. This current study was designed to explore categorical BMI judgement accuracy across the BMI spectrum, to determine whether there are inaccuracies at the either one or both extremes of the BMI spectrum, as predicted by these perceptual explanations.

5.1.2 *Other Factors Related to Body Size Estimation Accuracy*

Some research indicates that an individual's psychopathology modulates the accuracy of body size estimations for other bodies. For example, Moody et al. (2017) found that AN and Body Dysmorphic Disorder patients rated the weight of other female bodies significantly higher than non-clinical controls and Horndasch et al. (2015) found that AN patient's overestimated weight more than non-clinical controls, indicating a link between psychopathology and body size overestimation. Similarly, findings from Gledhill et al. (2019) suggest that higher eating disorder symptomology was associated with higher weight estimations and modulated the magnitude of error in both AN patients and non-clinical controls.

Vartanian et al. (2004) suggest that observer sex may influence visual judgements as men were more likely to underestimate female body weight (using photographs) than females, which may be due to a lack of point of reference in the opposite sex. For categorical BMI judgements, Robinson and Hogenkamp (2015) found higher same-sex accuracy for overweight/obese male bodies, whereas Oldham and Robinson (2016) did not find any effect of sex on BMI category accuracy for male bodies. Differences in male and female body ideals, such as the prominence and value of the thin-ideal for women in Western societies (Fouts & Burggraf, 1999; Grogan, 2016; Spitzer et al., 1999), may have implications for perceptions of body size (Glauert et al., 2009) i.e. the perception of a normal female body would be lower in BMI than that for males (Robinson, 2017). It is not uncommon for women to desire an ideal body size that is underweight or a low-normal BMI (e.g. Tovée et al., 2003; Tovée & Cornelissen, 2001; Wardle & Johnson, 2002). This may influence body norms and attitudes towards weight loss, such as attitudes that individuals above this ideal range should consider losing weight. Therefore, the influence of observer sex warrants further investigation.

Additionally, most previous studies presented photographed bodies from either one-angle (front-facing) or two-angles (front-facing and profile) (e.g. Gledhill et al., 2019; Oldham & Robinson, 2017). Some authors have suggested that using 3D stimuli or video footage would possibly result in more accurate body size estimations than static photographs from two-angles (Oldham & Robinson, 2016; Robinson & Hogenkamp, 2015). Video footage of a rotating body may be a good alternative to static images, as it presents the visual cues normally visible in the real world but in a controlled laboratory setting (Smith et al., 2007). Although, it may be argued that it is unnecessary as stomach depth is a key visual cue when judging body size, which is present when presenting a profile-view (Cornelissen et al., 2018) and presentation of both frontal and profile viewpoints together accurately captures body shape, encapsulating a variety of anthropometric and morphological variables (Cohen et al., 2015; Rilling et al., 2009). These studies imply that presenting a frontal and profile view should sufficiently capture the visual cues that are necessary for making precise body size judgements, so we may not expect additional viewpoints (i.e. 360-degrees) to significantly influence responses.

An alternative way to capture the body from 360-degrees is using 3D scanning technology, which may be a viable alternative for photographs and video footage due to the ease of capture and the ability to take static images or produce a fully moveable 3D stimulus. This may be advantageous as it enables the development of standardised body stimuli by applying the same high-quality, photorealistic texture to a range of 3D body shapes, limiting influence from extraneous factors (e.g. clothing, skin texture/colour, and appearance), which may be present in photographs and video footage, while retaining individual size/shape. Since 3D scans may be presented in 2D and life-sized/fully moveable in VR environments (e.g. Irvine et al., 2020; Perpiñá et al., 2003; Piryankova, Yu Wong et al., 2014), it is important to develop understanding of body perceptions using standardised 3D models and whether they are judged similarly to photographs/video footage.

5.1.3 *The Current Study*

Consequently, this current research was conducted to extend previous research investigating categorical perceptions of BMI weight status and attitudes towards weight loss, using 3D scans of female bodies varying in BMI from underweight to obese (according to World Health Organisation [WHO] BMI categories), in a sample of adults living in the UK. Factors which may potentially influence judgements such as observer characteristics (e.g. psychopathology, weight stigma, sex, and own BMI), and the amount of visual information available (two-angles or eight-angles) were explored.

5.2 Method

Ethical approval was gained from the University of Lincoln Research Ethics Committee (Project code: 0709).

5.2.1 *Aims*

The first aim of this study was to investigate visual weight status accuracy (according to WHO BMI labels: underweight, normal weight, overweight, and obese) using 3D scans of female bodies. It was hypothesized that patterns of accuracy would be explained by two perceptual explanations (contraction bias and the visual normalisation theory), such that lower BMI bodies would be overestimated, and higher BMI bodies would be underestimated.

The second aim was to investigate UK adults attitudes towards weight loss (i.e. whether others should consider losing weight) across the BMI spectrum, using 3D scans of female bodies.

The third aim was to identify whether the amount of visual information available (two-angles versus eight-angles) affected judgements.

The fourth aim was to investigate whether judgements of other bodies were modulated by factors related to the participant, such as sex and attitudinal factors associated with body image, self-esteem, mood, and weight-bias.

5.2.2 *Participants*

Participants were recruited through opportunity sampling (posts on social media websites, word-of-mouth and posters around the University of Lincoln) and Prolific (an online participant recruitment platform). Prolific respondents received £3.34 and psychology undergraduate students received course credits for participation. Participants were required to be currently residing in the UK, with English as their first language, and with no history or current diagnosis of an eating disorder. In total, 121 female and 106 male participants, aged 18 – 45 years old (M = 23.91, SD = 7.11) were recruited. The sample was predominantly Caucasian (92.48%) with 3.54% identifying as Asian, 2.21% as Black African or Black Caribbean, 1.77% as mixed ethnicity, and 0.44% unknown. The majority were heterosexual (82.82%), with 11.01% identifying as bisexual, 5.29% as homosexual, and 0.88% selecting the ‘prefer not to say’ option. Most respondents selected secondary education as their highest level of education (38.33%), followed by Certificate/Diploma of Higher Education (28.19%), undergraduate degree (20.71%), postgraduate degree (12.33%), and primary education (0.44%).

5.2.3 *Materials*

Body Stimuli. The stimulus set of 3D body shapes were selected from the database of 3D body scans described in Section 2.4, Chapter 2. Twenty-four 3D scans ranging in BMI from 16.69 to 38.05 (M = 25.09, SD = 6.53) were selected, with six bodies in each WHO BMI category (underweight, normal weight, overweight, and obese). The WHO BMI category definitions are reported in Section 2.1.1, Chapter 2).

Stimuli were matched for age, height, and Waist-to-Hip Ratio (WHR). One-way ANOVAs confirmed that there were no significant differences between the four BMI categories for age ($F(3, 20) = 0.03$, $p = .995$), height ($F(3, 20) = 1.01$, $p = .407$) and WHR ($F(3, 20) = 2.33$, $p = .105$). As expected, based on findings presented in Section 2.4, Chapter 2, skeletal muscle mass (kg) increases as body fat/BMI increases. Statistically significant differences in skeletal muscle mass were found between the four BMI categories ($F(3, 20) = 6.76$, $p = .003$). Tukey post-hoc comparisons suggest that there were significant differences between skeletal muscle mass in the underweight versus overweight ($M_{\text{Diff}} = 7.32$, $p = .008$) and obese ($M_{\text{Diff}} = 7.75$, $p = .005$) BMI categories. Informal qualitative feedback from colleagues was gained to gain verbal feedback about the amount of visible muscularity to ensure that stimuli were of a similar visual muscularity, despite statistically significant differences in values. Details of body characteristics for stimuli in each BMI category can be found in Table 5.1.

A standardized, computer-generated skin texture was applied to each of the 3D scans to reduce the impact of extraneous factors such as skin colour, attractiveness, skin blemishes, clothing etc. affecting judgements and to ensure that judgements were based on the size/shape of the body whilst maintaining as much ecological validity as possible. Heads were covered using a white cube to hide the individual's facial features, to avoid judgements being influenced by extraneous, non-standardised features e.g. facial attractiveness.

Table 5.1

Average anthropometric measurements for the stimuli in each BMI category.

	BMI		Age	Height	WHR	SMM
BMI Cat	*M* (SD)	Range	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
UW	17.49 (0.60)	16.69 – 18.19	22.83 (4.36)	159.58 (6.72)	0.79 (0.02)	22.18 (2.29)
NW	21.15 (1.54)	19.60 – 23.13	23.17 (2.48)	164.25 (5.34)	0.76 (0.06)	25.07 (1.50)
OW	27.56 (1.56)	25.65 – 29.51	23.33 (4.18)	164.83 (3.44)	0.80 (0.06)	29.50 (5.08)
OB	34.17 (2.22)	31.16 – 38.05	23.33 (3.33)	165.33 (8.98)	0.85 (0.07)	29.93 (3.95)

Abbreviations. BMI Cat = BMI Category, UW = Underweight, NW = Normal weight, OW = Overweight, OB = Obese, WHR = Waist-to-Hip Ratio, SMM = Skeletal Muscle Mass (kg).

Stimuli Presentation: Viewpoint Condition. There were two blocks of stimuli presentation, where each body stimulus was presented from two-angles in the two-angle viewpoint condition and eight-angles in the eight-angle viewpoint condition. This was a repeated measures design such that all participants viewed all stimuli in both conditions. The order of the conditions was randomised across participants, as was the presentation of body stimuli within each condition.

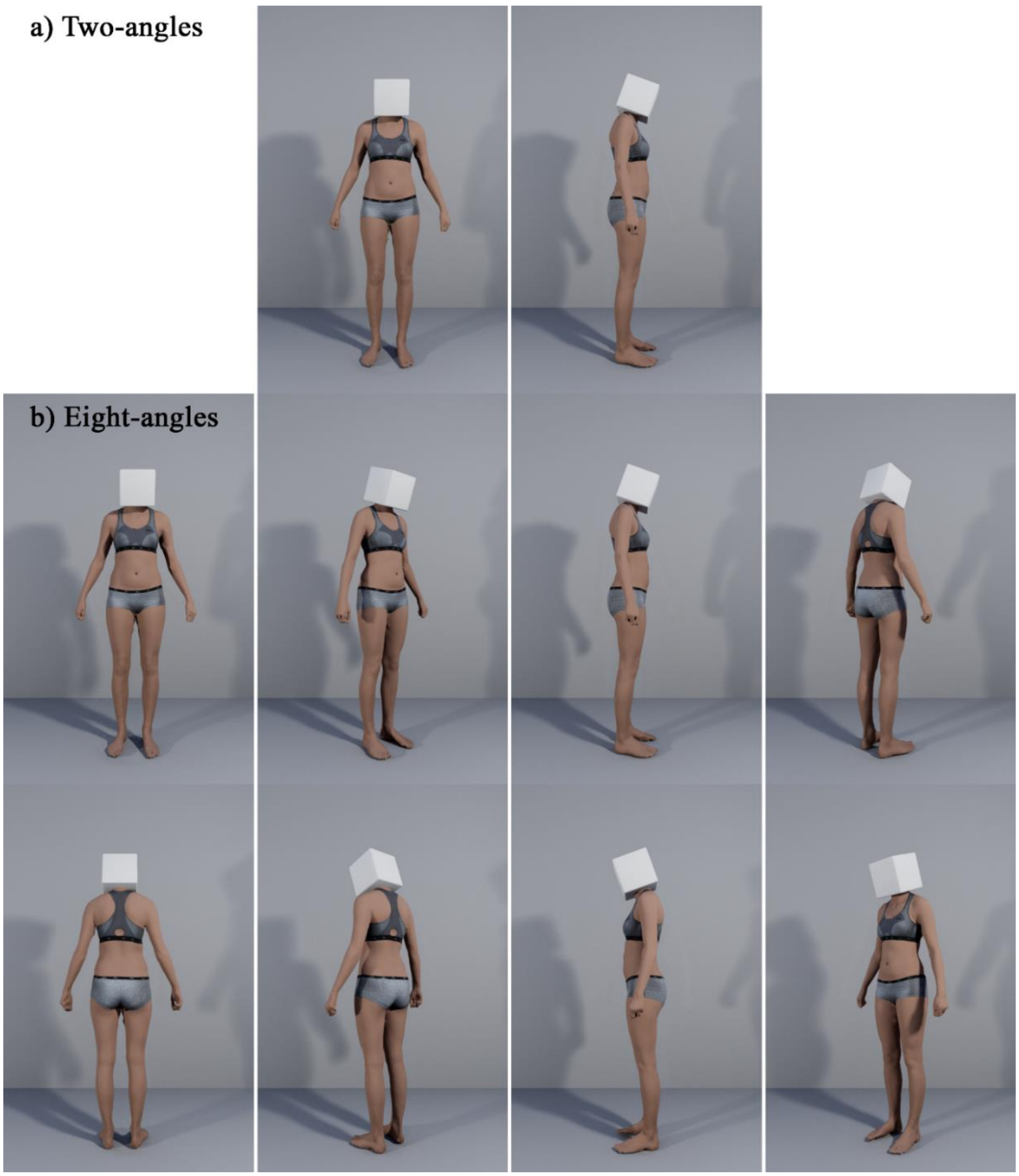
Two-angles. In the two-angle condition, a single image of each body stimulus was presented with the body presented at two angles (front-facing and profile).

Eight-angles. In the eight-angle condition, each body stimulus was presented using two images to maintain the same height and width as the two-angle condition. There were four-angles in each image and the images were displayed simultaneously, one above the other. For each body stimulus, the body was presented at eight angles at 45-degree intervals to cover the full 360-degree range.

All images were presented at the same size (614 x 1038 pixels). See Figure 5.1 for an example of a body stimulus in the two-angle and eight-angle conditions.

Figure 5.1

The top row (a) shows an example of a body stimulus presented in the two-angle condition. The middle and bottom rows (b) show an example of the same body stimulus presented in the eight-angle condition.



Psychometric Measures. The psychometric measures outlined in Section 2.2, Chapter 2 were used in this study to assess psychological and attitudinal factors related to body image, eating disorder psychopathology, self-esteem, and depression. In addition, measurements of weight bias internalisation and anti-fat attitudes (detailed below) were included.

Modified Weight Bias Internalization Scale (WBIS-M; Pearl & Puhl, 2014). Weight bias internalisation refers to when a person applies negative stereotypes and self-derogation based on their body weight. Internalisation of weight bias has been associated with negative mental health outcomes (Pearl & Puhl, 2018) and increased BMI, self-perceived body size, experience of weight stigma, and weight-loss efforts (Puhl et al., 2018). A scale to measure this was first developed by Durso and Latner (2008), assessing internalised weight bias in overweight/obese men and women in the United States. The scale demonstrated high internal consistency ($\alpha = 0.85$) and correlated with anti-fat attitudes and measures of psychopathology (self-esteem, drive for thinness, and body image concerns) when controlling for BMI. The final scale consisted of 11 items on a 7-point Likert scale from 1 (Strongly Disagree) to 7 (Strongly Agree).

The modified version of the scale was adapted to apply to individuals of all body sizes, by changing the wording on six of the items from ‘overweight’ to ‘my weight’. The WBIS-M has been shown to demonstrate high internal consistency ($\alpha = 0.94$) in individuals from the United States (Pearl & Puhl, 2014). The scale correlated with psychopathology similarly to the original scale when controlling for BMI and predicted psychopathology scores. Obese participants scored higher than people in other weight categories (based on self-reported BMI and perceived weight status category). Females scored significantly higher than males and sex moderated the relationship between WBIS-M and drive for thinness but not any other psychopathology measure. Overall, a systematic review stated that the WBIS-M had good internal consistency, theoretical clarity, content validity, convergent validity, and discriminant validity (Lacroix et al., 2017).

Scores were calculated by summing answers on the zero to nine scale, with items one and nine being reverse scored. A higher score indicates higher weight bias internalisation.

Anti-Fat Attitudes (AFA) Questionnaire (Crandall, 1994). The AFA questionnaire was developed to assess explicit anti-fat attitudes and prejudice against fat people. The scale comprises 13-items on a 10-point Likert scale from 0 (Very Strongly Disagree) to 9 (Very Strongly Agree). There are three subscales: Dislike (prejudice towards fat people e.g. “I have a hard time taking fat people too seriously”), Fear of Fat (an individual's personal concern about fatness e.g. “I feel disgusted with myself when I gain weight”) and Willpower (beliefs regarding the personal controllability of weight and the belief that being overweight is a result of a lack of control e.g. “Some people are fat because they have no willpower”).

Each subscale has been demonstrated to have high internal consistency (α =.84, .79, and .66 for Dislike, Fear of Fat and Willpower, respectively) (Crandall, 1994). A systematic review by Lacroix et al. (2017) concluded that the scale showed excellent psychometric evidence and fulfilled all criteria: internal consistency, test-retest reliability, sensitivity to change, theoretical clarity, and content, structural, convergent and discriminant validity.

Scores were calculated individually for each of the subscales by summing answers on the zero to nine scale and dividing by the number of items (7, 3 and 3 for Dislike, Fear of Fat and Willpower, respectively). A higher score indicates higher explicit anti-fat attitudes.

In this sample, for BSQ, EDE-Q Global, RSE, BDI, SATAQ-4 Thin Ideal Internalisation, SATAQ-4 Athletic Ideal Internalisation, WBIS-M, AFA dislike, AFA fear of fat, and AFA Willpower, Cronbach's alpha was .96, .94, .92, .92, .79, .91, .94, .91, .88, and .87, respectively.

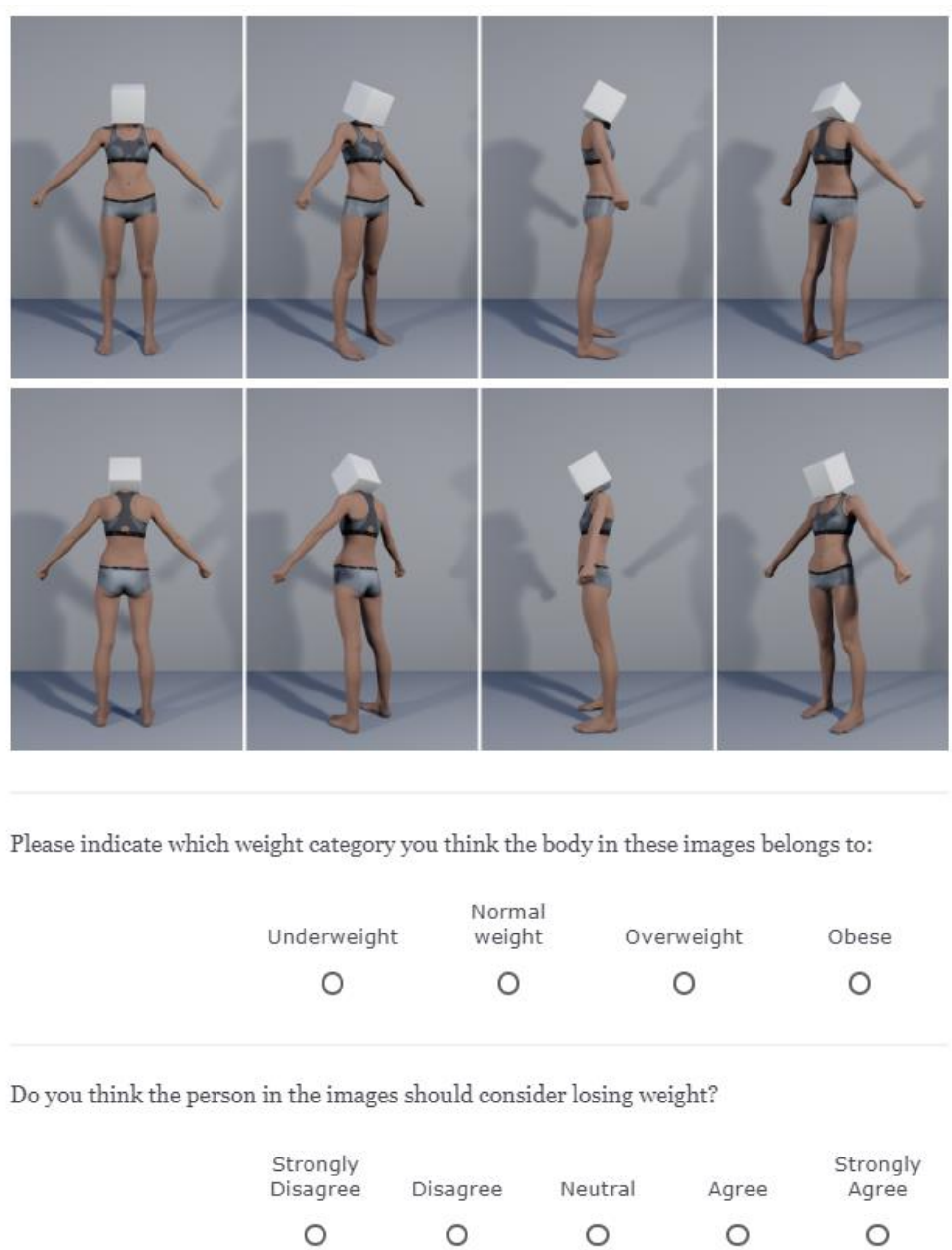
Body Measurements. The participant's body measurements were collected using self-report. Participants were asked to provide their height and weight and to categorise their own weight status according to four BMI categories (underweight, normal weight, overweight, or obese). Each participant's BMI was then calculated using the BMI equation outlined in Section 2.1.1, Chapter 2.

5.3 Procedure

The study was conducted online via Qualtrics. Participants were first presented with the information sheet and consent form. A series of questions were asked to determine eligibility: current or previous diagnosis of an eating disorder (yes/no), currently living in the UK (yes/no) and the type of device being used for survey completion (computer/tablet/mobile phone/laptop). Based on those answers, participants were able to continue or were excluded from participation by survey termination. Next, eligible participants completed some demographic questions: sex (cis-gender/as assigned at birth), age, ethnicity, sexual orientation, highest level of education, annual income in Great British Pounds, and provided their body measurements. Participants were then shown the body stimuli and were asked to indicate which BMI weight category they thought each stimulus belonged to (underweight/normal weight/overweight/obese) and whether they thought the person in the images should consider losing weight on a 5-point scale from 1 (Strongly Disagree) to 5 (Strongly Agree) (see Figure 5.2). Lastly, psychometric measures were completed in a random order, and all participants were debriefed using a written debrief form. Participation took approximately 40 minutes.

Figure 5.2

An example of a stimulus in the eight-angle condition and the two questions displayed to participants below each stimulus.



5.4 Data Analysis

Analyses were conducted using R Studio (R Version 3.6.3). The weight status category of the stimulus according to WHO BMI labels was coded from 1 to 4 (1, underweight; 2, normal weight; 3, overweight; 4, obese). The participant's judgement of BMI weight status category was coded on the same 1 - 4 scale, to allow for comparison. The accuracy of categorical judgements was calculated by subtracting the participant's categorical response from the category of the stimulus. A negative value indicates underestimation of BMI category, 0 indicates an accurate response, and a positive value indicates overestimation of BMI category. This also gives the degree of accuracy with 1 indicating mis-estimation by 1 BMI category, 2 by 2 BMI categories etc. Since each stimulus was a 3D body scan from the database (see Section 2.4, Chapter 2) and was therefore associated with a range of body composition values, the actual BMI of the stimulus was also used in analyses (descriptive statistics are presented in Table 5.1).

5.5 Results

5.5.1 *Participant Characteristics*

A summary of participant characteristic information can be found in Table 5.2. The majority of participants (72.25%) categorised themselves as a normal weight, 20.70% as overweight, 3.97% as underweight, and 3.08% as obese. There was a significant positive correlation between self-reported BMI and self-perceived BMI category ($r_s = 0.71$, $p < .001$, n = 225) indicating good consistency between the two measurements. There were no significant differences between male and female BMI ($p > .05$) however, males were significantly older than females ($p < .001$), determined using Mann-Whitney Tests.

Table 5.2

Summary of participant characteristics.

	Males	Females	Overall	
Participant Characteristic	*M* (SD)	*M* (SD)	*M* (SD)	Range
Age (n = 227)	26.56 (7.44)	21.60 (5.97)	23.91 (7.13)	18.00 – 45.00
BMI (n = 225)	24.04 (4.52)	23.68 (4.46)	23.85 (4.48)	15.70 – 38.94
Self-perceived Weight Status (n = 227)	2.17 (0.56)	2.28 (0.57)	2.23 (0.57)	1.00 – 4.00

5.5.2 *Psychometric Measures*

Descriptive statistics for psychometric data for the whole sample (n = 227), and male (n = 106) and female (n = 121) observers separately are presented in Table 5.3.

Table 5.3

Descriptive statistics (mean, standard deviation, and range) for each psychometric measure.

	Males	Females	Overall	
Psychometric Measure	*M* (SD)	*M* (SD)	*M* (SD)	Range
EDE-Q Dietary Restraint	0.69 (0.93)	1.33 (1.20)	1.19 (1.30)	0.00 – 5.40
EDE-Q Eating Concerns	0.69 (0.93)	1.23 (0.80)	0.95 (1.13)	0.00 – 4.80
EDE-Q Shape Concerns	1.67 (1.26)	1.63 (2.88)	2.31 (1.59)	0.00 – 6.00
EDE-Q Weight Concerns	1.32 (1.23)	1.64 (2.40)	1.94 (1.57)	0.00 – 5.80
EDE-Q Global	1.16 (0.97)	1.98 (1.28)	1.60 (1.21)	0.00 – 5.25
RSES Total	19.33 (5.83)	17.19 (5.73)	18.19 (5.86)	4.00 – 30.00
BDI Total	8.80 (8.58)	12.13 (9.80)	10.58 (9.38)	0.00 – 50.00
BSQ Total	35.35 (14.62)	49.09 (18.45)	42.67 (18.14)	16.00 – 91.00
Thin Ideal	2.84 (0.85)	3.09 (0.94)	2.97 (0.90)	1.00 – 5.00

	Males	Females	Overall	
Psychometric Measure	*M* (SD)	*M* (SD)	*M* (SD)	Range
Athletic Ideal	3.25 (1.02)	2.67 (1.04)	2.94 (1.07)	1.00 – 5.00
WBIS-M Total	32.18 (14.84)	41.11 (15.48)	36.94 (15.79)	11.00 – 73.00
AFA Dislike	2.25 (1.99)	1.26 (1.47)	1.72 (1.80)	0.00 – 9.00
AFA Fear of Fat	3.35 (2.52)	5.03 (2.85)	4.25 (2.82)	0.00 – 9.00
AFA Willpower	5.41 (2.22)	3.57 (2.23)	4.43 (2.40)	0.00 – 9.00

Abbreviations. Thin Ideal = SATAQ-4 Thin Ideal Internalisation, Athletic Ideal = SATAQ-4 Thin Ideal Internalisation

As in Chapter 3, Principal Component Analysis (PCA) was used to create latent variable/s for subsequent analyses. All details of the PCA can be found in Appendix F. Two latent variables: ‘psych’ and ‘fat attitudes’ were derived. ‘Psych’ represents psychological concerns (a combination of attitudes related to body image and negative attitudes towards the self, e.g. disturbed attitudes to eating, body dissatisfaction and negative affect), with higher scores indicating higher concerns (range: -1.66 – 2.62). ‘Fat attitudes’ represents an expression of anti-fat attitudes and the internalisation of an athletic physique ideal, with higher scores indicating higher anti-fat attitudes and athletic-ideal internalisation (range: -2.45 – 3.11). Table 5.4 displays the descriptive statistics of ‘psych’ and ‘fat attitudes’, for males and females separately.

Table 5.4

Mean, standard deviation, minimum, and maximum 'psych' and 'fat attitudes' scores for male and female observers.

	Males				Females			
	M	SD	Min	Max	M	SD	Min	Max
'psych'	-0.39	0.81	-1.66	1.97	0.34	1.03	-1.55	2.62
'fat att'	0.38	1.00	-1.89	3.11	-0.33	0.88	-2.45	2.63

Abbreviations. 'fat att' = 'fat attitudes'

5.5.3 *Accuracy of BMI Category Judgements*

First, Spearman's Rank correlations were conducted to assess the relationship between the participants BMI category response and the BMI and BMI category of the stimuli. Correlation coefficients were significant and positive ($r_s > .77$; see Table 5.5) suggesting that as the BMI of the stimulus increased, as did the participant's judgements of BMI category. This indicates that participants were generally able to perceive increases in stimulus BMI. For the correlations, the total number of observations were included as each participant (n = 227) responded to each stimulus (n = 24) twice (once in the two-angle condition and once in the eight-angle condition). The number of observations for the whole sample when including all the data (responses for each stimulus in both the two- and eight-angle conditions) = 10896, for the females = 5808, and for the males = 5088. The number of observations for the two-angle condition only = 5488, for the females = 2904, and for the males = 2544. The number of observations for the eight-angle condition only = 5488, for the females = 2904, and for the males = 2544.

Table 5.5

Correlations between BMI category response and the BMI/BMI category of the stimuli.

	Scan BMI			BMI Category		
	All data	Two-angle	Eight-angle	All data	Two-angle	Eight-angle
Whole sample	.79***	.79***	.79***	.79***	.79***	.79***
Females	.77***	.77***	.77***	.77***	.77***	.77***
Males	.81***	.81***	.81***	.81***	.80***	.82***

*** $p < .001$, ** $p < .005$, * $p < .05$

To investigate BMI category response accuracy, the percentage of responses for each degree of accuracy was calculated for each BMI category and each viewpoint condition (two-angles or eight-angles), separately for male and female observers; presented in Table 5.6.

Table 5.6

Percentage of responses for each degree of accuracy, for each stimulus BMI category, viewpoint condition, and observer sex.

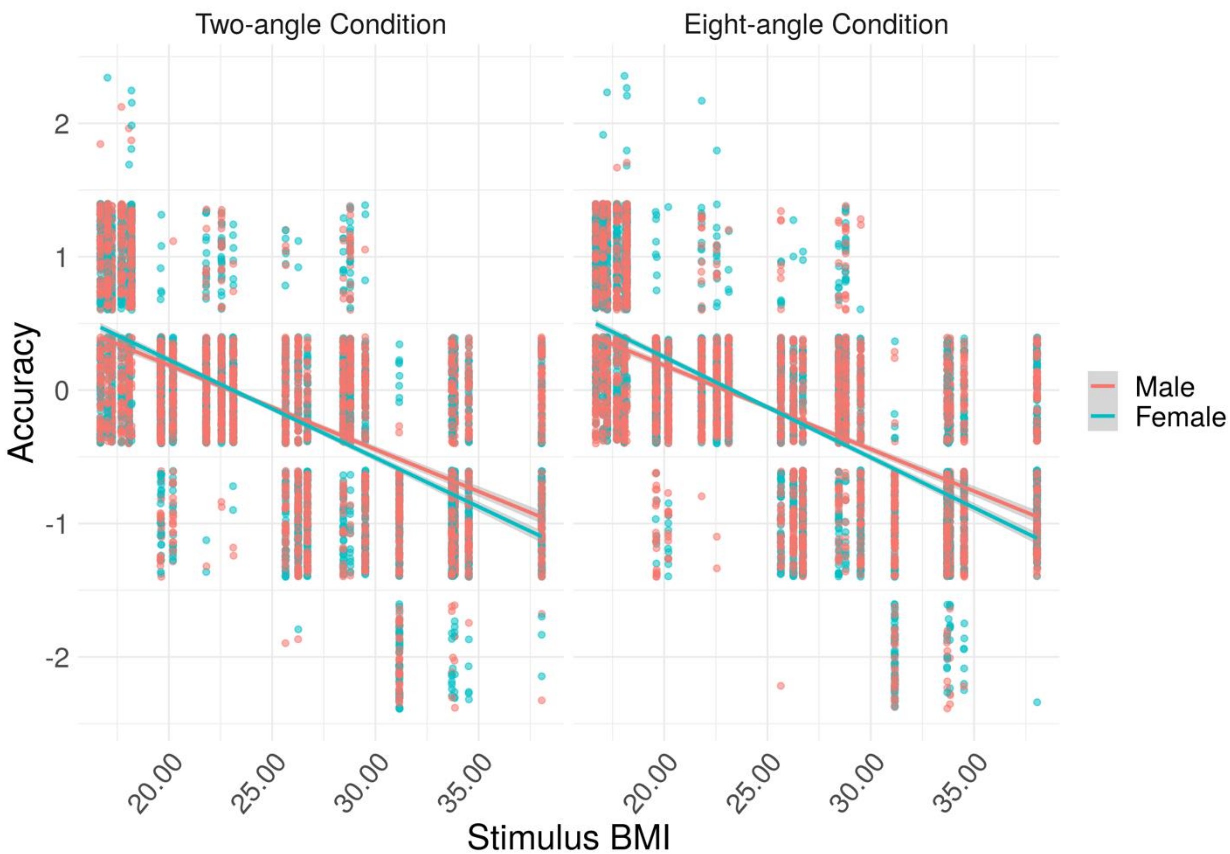
Observer Sex	Stimulus BMI Category	-2	-1	0	+1	+2
Two-angle Condition						
Males	UW	-	-	44.97	54.40	0.73
	NW	-	6.60	89.15	4.25	0.00
	OW	0.31	39.94	55.35	4.40	-
	OB	7.08	56.60	36.32	-	-
Females	UW	-	-	38.02	61.16	0.82
	NW	-	6.47	87.19	6.34	0.00
	OW	0.14	45.59	48.76	5.51	-
	OB	9.64	61.71	28.65	-	-
Eight-angle Condition						
Males	UW	-	-	45.91	53.77	0.32
	NW	-	5.34	91.67	2.99	0.00
	OW	0.16	39.94	55.03	4.87	-
	OB	6.92	56.45	36.64	-	-
Females	UW	-	-	37.88	61.16	0.96
	NW	-	2.07	92.42	5.23	0.28
	OW	0.00	43.94	51.10	4.96	-
	OB	10.47	61.02	28.51	-	-

Note. UW = underweight, NW = normal weight, OW = overweight, and OB = obese. Dashes denote where a response is not possible i.e., for obese bodies it was not possible to overestimate the bodies.

As demonstrated in Table 5.6, accuracy was highest for the normal weight BMI category (> 87% of responses were correct). Accuracy was lower for the underweight and overweight BMI categories, with around half of the responses overestimating underweight bodies and around half underestimating overweight bodies. Accuracy was lowest for the body stimuli in the obese BMI category, where only around a third of responses were correct. Figure 5.3 demonstrates the relationship between accuracy and stimulus BMI.

Figure 5.3

The relationship between stimulus BMI and BMI categorization accuracy.



One sample t-tests indicated that mean accuracy was significantly different from 0, with 0 being complete accuracy, in all but the normal weight BMI category for both the two-angle and eight-angle conditions. Mean accuracy and significance values of the one-sample t-tests are presented in Table 5.7. This suggests that, on average, only the bodies in the normal weight category were accurately categorised by participants. As can be seen by the direction of the mean accuracy, underweight bodies tended to be overestimated whereas overweight and obese bodies tended to be underestimated. Percentage and mean accuracy in each viewpoint condition was similar.

Table 5.7

Mean accuracy and one-sample t-tests for each viewpoint condition.

	All data	Two-angle	Eight-angle
	M (SD)	*M* (SD)	*M* (SD)
Underweight	0.59 (0.51) ***	0.60 (0.51) ***	0.59 (0.51) ***
Normal weight	0.00 (0.32)	-0.01 (0.35)	0.01 (0.29)
Overweight	-0.38 (0.58) ***	-0.38 (0.58) ***	-0.37 (0.58) ***
Obese	-0.76 (0.59) ***	-0.76 (0.59) ***	-0.77 (0.60) ***

*** $p < .001$, ** $p < .005$, * $p < .05$

Spearman's Rank correlations were conducted to investigate the relationship between accuracy and stimulus BMI. The results indicated that there was a significant negative correlation between accuracy and stimulus BMI/BMI category, such that an increase of stimulus BMI was associated with decreased accuracy in the form of underestimation and a decrease of stimulus BMI was associated with overestimation. Table 5.8 presents the correlation coefficients and significance values for each viewpoint condition and participant sex separately. The number of observations for each correlation are detailed on page 209, Section 5.5.3.

Table 5.8

The relationship between stimulus BMI/BMI category and accuracy.

	Stimulus BMI			BMI Category		
	All data	Two-angle	Eight-angle	All data	Two-angle	Eight-angle
Whole sample	-.65***	-.65***	-.66***	-.70***	-.70***	-.70***
Females	-.68***	-.67***	-.69***	-.72***	-.72***	-.73***
Males	-.62***	-.62***	-.62***	-.67***	-.67***	-.67***

*** $p < .001$, ** $p < .005$, * $p < .05$

Next, Spearman's Rank correlations were conducted to investigate the relationship between accuracy and participant characteristics/attitudinal measures for the whole sample and all observations of accuracy (n = 10896). There were weak, significant, positive correlations between accuracy and 'psych' ($r_s = .05$, $p < .001$) and 'fat attitudes' ($r_s = .13$, $p < .001$). There were no significant correlations between accuracy and participant characteristics (BMI, age, self-perceived weight status; all *p*s > .05).

Linear Mixed-Effects Model of BMI Category Accuracy. A linear mixed-effects model was used to predict accuracy using the 'lme' function from the 'nlme' package (Version 3.1-151; Pinheiro et al., 2020). Based on the hypotheses, five fixed effects were considered for inclusion in the model (participant sex, stimulus BMI, viewpoint, 'psych', and 'fat attitudes'). First, to determine whether the inclusion of random effects on the intercept were warranted, a series of models were run and compared using AIC/BIC values and Likelihood Ratio Tests: i) an intercept only model, ii) a random intercept model allowing variation from participants, ii) a random intercept model allowing variation from stimuli, and iv) a random intercept model allowing variation from both participants and stimuli. The model including random intercepts for both participants and stimuli was warranted the best model fit for the data due to decreased AIC and BIC values and significant reductions in Log-Likelihood.

Next, a series of models, comparing the addition of each of the fixed effects were run. Model comparisons of AIC, BIC, and Log-Likelihood indicated that the best model fit included all five fixed effects and interaction terms, and random intercepts for both participants and stimuli. Final model:

$$y_i = \beta_0 + \beta_1 x_1 * \beta_2 x_2 * \beta_3 x_3 * \beta_4 x_4 * \beta_5 x_5 + u_{j1} + u_{j2} + \epsilon_{ij1j2}$$

y_i = Accuracy, x_1 = stimulus BMI, x_2 = participant sex, x_3 = 'psych', x_4 = 'fat attitudes', x_5 = viewpoint, u_{j1} = random intercept of the participant (participant ID), u_{j2} = random intercept of the stimuli (stimulus ID), and ϵ_{ij1j2}= residual error.

The 'r.squaredGLMM' function from the 'MumIn' package (Version 1.43.17; Bartoń, 2020) was used to calculate conditional R^2 for the final model of accuracy, showing that the model explained approximately 79% of the variance in the data. A fully summary of the model can be found in Appendix F.

There were significant Type III fixed effects of stimulus BMI ($F(1, 22) = 39.97$, $p < .001$) and participant sex ($F(1, 5410) = 25.28$, $p < .001$) on accuracy. There were significant two-way interactions between stimulus BMI and participant sex ($F(1, 5410) = 20.07$, $p < .001$), stimulus BMI and 'psych' ($F(1, 5410) = 4.38$, $p < .001$), and participant sex and viewpoint condition ($F(1, 5410) = 7.20$, $p < .001$). There were significant three-way interactions between stimulus BMI, 'psych' and 'fat attitudes' ($F(1, 5410) = 7.13$, $p = .008$), stimulus BMI, participant sex and viewpoint ($F(1, 5432) = 3.89$, $p = .049$), 'psych', participant sex and viewpoint ($F(1, 5432) = 14.84$, $p < .001$), and 'psych', 'fat attitudes' and viewpoint ($F(1, 5432) = 4.18$, $p = .041$).

Since all terms involved in the two- and three-way interactions were part of significant higher-order four-way interactions, post-hoc analyses were used to explore the significant four-way interaction terms. Pairwise comparisons were conducted using the ‘emmeans’ function from the ‘emmeans’ package (Version 1.4.7; Lenth et al., 2020) corrected for multiple comparisons using the Tukey method of adjustment. Five levels of stimulus BMI were used: minimum (underweight), 16.69; -1SD (the boundary of underweight to normal weight, 18.56; mean (the boundary of normal weight to overweight), 25.09; +1SD (boundary overweight and obese), 31.62; maximum (obese class II), 38.05. Three levels of ‘psych’ and ‘fat attitudes’ were used: -1SD, low; mean; +1SD, high.

There was a significant four-way interaction between stimulus BMI, participant sex, ‘psych’, and viewpoint condition ($F(1, 5432) = 15.76$, $p < .001$). As shown in Figure 5.4, lower BMI bodies were typically overestimated whereas higher BMI bodies were underestimated, demonstrating perceptual inaccuracies consistent with the contraction bias explanation. The evidence of underestimation of higher BMI bodies also supports the visual normalisation theory hypothesis. Pairwise comparisons for each level of ‘psych’ revealed that there were no significant differences between accuracy in the two- versus the eight-angle condition at any level of BMI for male (ps > .05) or female (ps > .05) observers. This suggests that accuracy for each sex did not significantly differ depending on the amount of visual information available. There were significant differences in accuracy between sexes across the BMI spectrum (see Table 5.9). These differences indicated that females overestimated underweight and low-normal weight BMI bodies (BMI at the minimum and -1SD) significantly more than males did, indicative of greater accuracy for male observers. Slight differences were found depending on ‘psych’ level and viewpoint condition, where sex differences for normal weight BMIs were significant at -1SD and mean of ‘psych’ in the two-angle condition, but mean and +1SD levels of ‘psych’ in the eight-angle condition. Significant differences between male and female observers were found at the maximum BMI level (obese class II) when ‘psych’ was at the mean level or high (+1SD), with males being more accurate in the eight-angle condition but not the two-angle condition. In both viewpoint conditions, increases mean accuracy becomes closer to 0 as ‘psych’ increases, indicating less under-/over-estimation for those with higher body concerns/negative affect. All predicted means for accuracy and pairwise comparisons of the difference between male and female accuracy, for each level of BMI, ‘psych’, and viewpoint condition are presented in Table 5.9.

Figure 5.4

A plot of predicted categorical BMI accuracy across the BMI spectrum, for each level of 'psych' (rows), for each viewpoint condition (columns) and each observer sex (coloured lines).

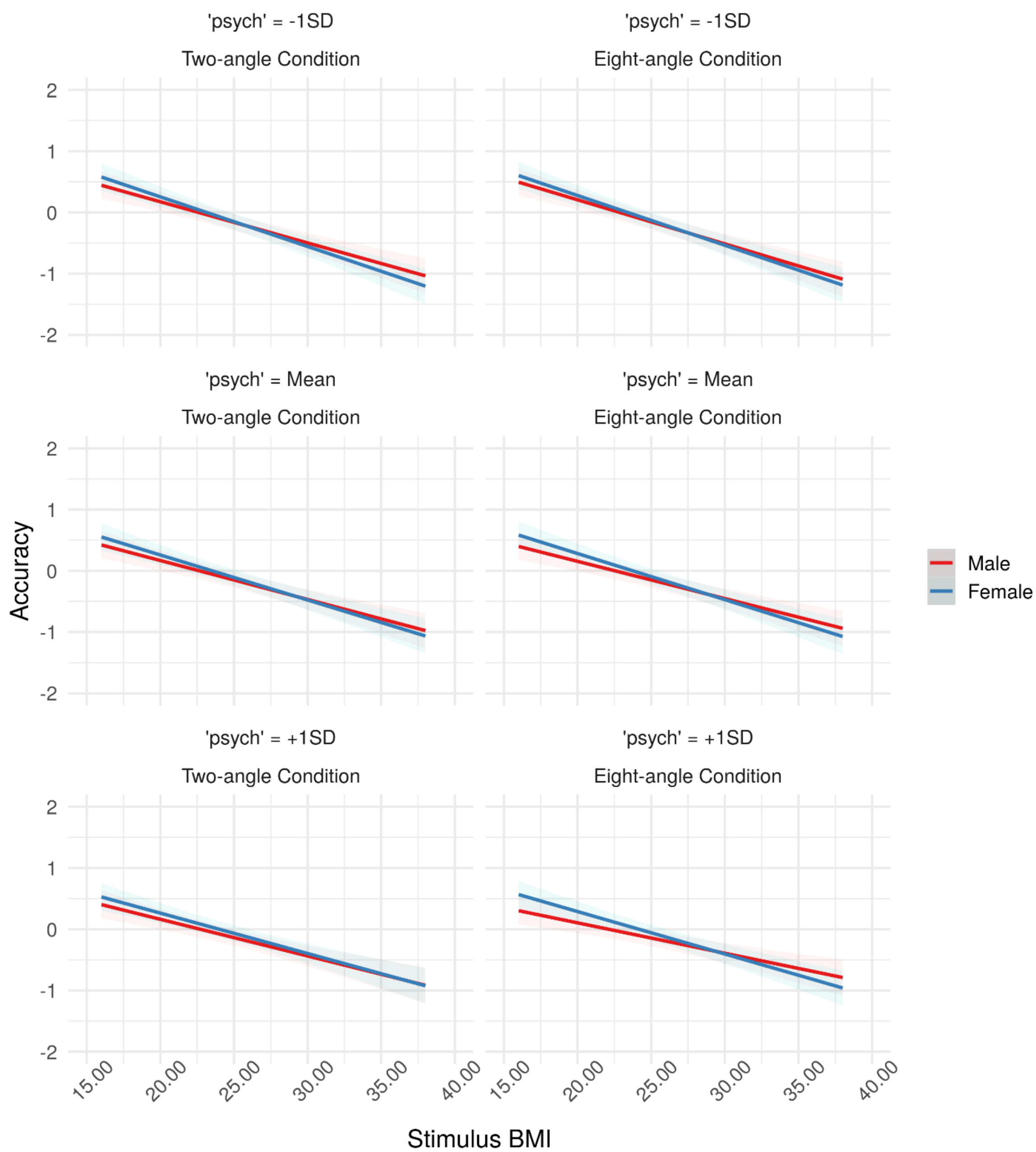


Table 5.9

Pairwise comparisons between male and female accuracy, for each level of BMI, 'psych', and viewpoint condition.

	$M_{Females}$	M_{Males}	$M_{Difference}$	SE	*p*
Two-angle Viewpoint Condition					
'psych' = -1SD					
BMI 16.69	0.52	0.40	-0.12	0.03	.010
BMI 18.57	0.37	0.27	-0.10	0.03	.033
BMI 25.09	-0.16	-0.17	-0.01	0.02	> .05
BMI 31.62	-0.69	-0.61	0.08	0.03	> .05
BMI 38.05	-1.21	-1.04	0.17	0.04	.012
'psych' = Mean					
BMI 16.69	0.50	0.38	-0.12	0.02	< .001
BMI 18.57	0.36	0.26	-0.11	0.02	< .001
BMI 25.09	-0.12	-0.16	-0.04	0.01	> .05
BMI 31.62	-0.60	-0.57	0.03	0.02	> .05
BMI 38.05	-1.07	-0.98	0.09	0.03	> .05
'psych' = +1SD					
BMI 16.69	0.48	0.36	-0.12	0.04	> .05
BMI 18.57	0.36	0.25	-0.11	0.03	.038
BMI 25.09	-0.07	-0.14	-0.07	0.02	> .05
BMI 31.62	-0.50	-0.53	-0.03	0.03	> .05
BMI 38.05	-0.93	-0.92	0.01	0.02	> .05
Eight-angle Viewpoint Condition					
'psych' = -1SD					
BMI 16.69	0.54	0.44	-0.10	0.03	> .05
BMI 18.57	0.39	0.31	-0.08	0.03	> .05
BMI 25.09	-0.14	-0.16	-0.02	0.02	> .05
BMI 31.62	-0.67	-0.63	0.04	0.03	> .05
BMI 38.05	-1.19	-1.09	0.10	0.04	> .05
'psych' = Mean					
BMI 16.69	0.53	0.36	-0.18	0.02	< .001
BMI 18.57	0.39	0.24	-0.15	0.02	< .001
BMI 25.09	-0.10	-0.15	-0.05	0.01	.029
BMI 31.62	-0.59	-0.55	0.04	0.02	> .05
BMI 38.05	-1.08	-0.94	0.13	0.03	.005
'psych' = +1SD					
BMI 16.69	0.52	0.27	-0.21	0.04	< .001
BMI 18.57	0.39	0.18	-0.21	0.03	< .001
BMI 25.09	-0.06	-0.15	-0.09	0.02	.012
BMI 31.62	-0.52	-0.47	0.05	0.03	> .05
BMI 38.05	-0.96	-0.79	0.17	0.05	.039

There was a significant four-way interaction between stimulus BMI, viewpoint condition, ‘psych’, and ‘fat attitudes’ ($F(1, 5432) = 4.64$, $p = .031$). Again, this demonstrates evidence of contraction bias for BMI category accuracy, as there is evidence of overestimation of BMI category at the lower end of the BMI spectrum (mean accuracy between 0 and +1, on average) and there is underestimation at the higher end of the BMI spectrum with increasing underestimation as BMI increases (up to one BMI category for bodies in the obese class II category). Pairwise comparisons for each level of ‘psych’ and ‘fat attitudes’ revealed that there were no significant differences between accuracy in the two- and eight- angle conditions at any level of BMI (*p*s > .05). This suggests that accuracy did not significantly differ depending on the amount of visual information available when controlling for psychological/attitudinal factors, however different patterns of accuracy were observed when considering differences between the latent factors (‘psych’ and ‘fat attitudes’) at different levels of BMI (see Table 5.10). For obese bodies (+1SD and maximum) pairwise comparisons at each level of ‘fat attitudes’ indicated significant differences in accuracy between those with high (+1 SD) and low (-1SD) ‘psych’ scores, in the eight-angle condition but not in the two-angle condition. In both viewpoint conditions, there were significant differences in accuracy between high and low levels of ‘psych’ for those with low ‘fat attitudes’ scores, for overweight and obese BMIs (mean and +1SD). In both cases, those with higher ‘psych’ scores (higher body concerns/negative affect) were significantly more accurate. For low-normal weight bodies, there were no significant differences between high and low ‘psych’ scores at any level of ‘fat attitudes’ in the two-angle condition, suggesting that body concerns/negative affect did not significantly modulate accuracy. However, in the eight-angle condition, there were significant differences for low-normal weight bodies between high and low ‘psych’ scores for mean and high ‘fat attitudes’ scores, where high body concerns/negative affect was associated with greater accuracy. As demonstrated by the shallower slopes in Figure 5.5 and mean accuracy values in Table 5.10, those with increased ‘psych’ scores tend to be more accurate across the BMI spectrum. Similarly, as can be seen in Table 5.10, those with higher ‘fat attitudes’ scores demonstrated mean accuracy values closer to 0 for overweight and obese BMIs (mean, +1 SD and maximum), suggesting that higher anti-fat attitudes are associated with more accurate estimations at the higher end of the BMI spectrum, particularly when body concerns/negative affect are also high. Mean accuracy and pairwise comparisons between high and low levels of ‘psych’ for each level of ‘fat attitudes’, BMI, and viewpoint condition are presented in Table 5.10.

Figure 5.5

A plot of predicted categorical BMI accuracy across the BMI spectrum, for each level of 'fat attitudes' (rows), for each viewpoint condition (columns) and each level of 'psych' (coloured lines).

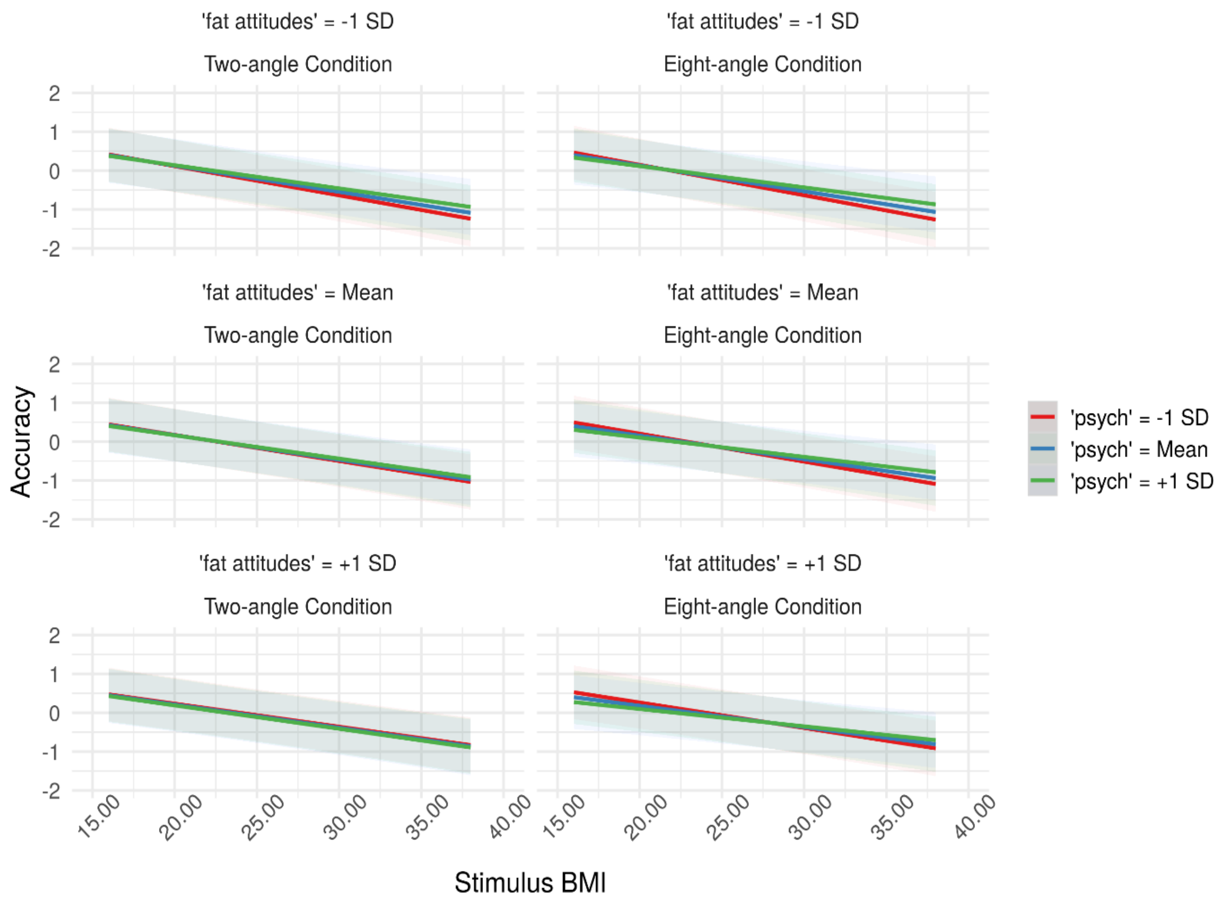


Table 5.10

Pairwise comparisons between low (-1SD) and high (+1SD) levels of 'psych', for each level of stimulus BMI, 'fat attitudes', and viewpoint condition.

	$M_{\text{'psych'-1SD}}$	$M_{\text{'psych'+1SD}}$	$M_{\text{Difference}}$ ('psych'-1SD vs 'psych'+1SD)	SE	p
Two-angle Viewpoint Condition					
'fat attitudes' = -1SD					
BMI 16.69	0.40	0.38	0.02	0.03	> .05
BMI 18.57	0.25	0.26	-0.01	0.03	> .05
BMI 25.09	-0.28	-0.17	-0.11	0.02	< .001
BMI 31.62	-0.83	-0.61	-0.22	0.03	< .001
BMI 38.05	-1.35	-1.03	-0.32	0.04	< .001
'fat attitudes' = Mean					
BMI 16.69	0.46	0.42	0.04	0.02	> .05
BMI 18.57	0.32	0.30	0.02	0.02	> .05
BMI 25.09	-0.16	-0.10	-0.06	0.01	.010
BMI 31.62	-0.65	-0.52	-0.13	0.02	< .001
BMI 38.05	-1.12	-0.92	-0.20	0.03	< .001
'fat attitudes' = +1SD					
BMI 16.69	0.52	0.46	0.06	0.03	> .05
BMI 18.57	0.39	0.35	0.04	0.03	> .05
BMI 25.09	-0.04	-0.04	0.00	0.02	> .05
BMI 31.62	-0.47	-0.43	-0.04	0.03	> .05
BMI 38.05	-0.89	-0.80	-0.09	0.04	> .05
Eight-angle Viewpoint Condition					
'fat attitudes' = -1SD					
BMI 16.69	0.42	0.38	0.04	0.03	> .05
BMI 18.57	0.26	0.25	0.01	0.03	> .05
BMI 25.09	-0.27	-0.17	-0.10	0.02	< .001
BMI 31.62	-0.81	-0.60	-0.21	0.03	< .001
BMI 38.05	-1.34	-1.03	-0.32	0.04	< .001
'fat attitudes' = Mean					
BMI 16.69	0.49	0.39	0.10	0.02	< .001
BMI 18.57	0.35	0.28	0.07	0.02	.070
BMI 25.09	-0.14	-0.10	-0.04	0.01	> .05
BMI 31.62	-0.65	-0.49	-0.16	0.02	< .001
BMI 38.05	-1.14	-0.88	-0.26	0.03	< .001
'fat attitudes' = + 1SD					
BMI 16.69	0.57	0.41	0.16	0.08	< .001
BMI 18.57	0.43	0.31	0.13	0.03	< .001
BMI 25.09	-0.03	-0.04	0.01	0.02	> .05

	$M_{\text{‘psych’-1SD}}$	$M_{\text{‘psych’+1SD}}$	$M_{\text{Difference}}$ (‘psych’-1SD vs ‘psych’+1SD)	SE	*p*
BMI 31.62	-0.49	-0.39	-0.10	0.03	.020
BMI 38.05	-0.94	-0.72	-0.22	0.04	< .001

Overall, these findings indicate that the accuracy of BMI weight status categorization is influenced by the BMI of the body, in that accuracy is highest for female bodies in the normal BMI category. There is overestimation of lower BMI bodies and underestimation of higher BMI bodies, with the magnitude of error increasing as BMI gets to the extremes. Estimates from the mixed-effect model indicate that mean accuracy ranges from 0.5 for underweight bodies to -1 for obese class II bodies, suggesting that, on average, obese bodies are often perceived as overweight. Evidence indicated that accuracy was modulated by observer sex, whereby male observers were slightly more accurate at estimating the BMI category of a female body across the BMI spectrum. The amount of visual information available (two-angles or eight-angles) did not have a significant effect on accuracy but different patterns of accuracy were found as part of three-way and four-way interactions. Psychological concerns and fat attitudes also modulated accuracy across the BMI spectrum and interactions between these attitudes had a small effect on accuracy.

5.5.4 *Attitudes to Weight Loss*

Descriptive statistics for mean weight loss ratings for each BMI category and observer sex are reported in Table 5.11. There was stronger agreement that obese females should lose weight, demonstrated by the higher mean ratings. There was a general disagreement that underweight female bodies should lose weight, demonstrated by the means below 2.00.

Table 5.11

Mean weight loss ratings for each BMI category for the whole sample and male and female observers separately.

Stimulus BMI Category	Males	Females	Overall	
	M (SD)	*M* (SD)	*M* (SD)	Range
Two-angle Viewpoint Condition				
Underweight	1.62 (0.69)	1.70 (0.75)	1.66 (0.72)	1.00 – 4.00
Normal weight	2.16 (0.84)	2.20 (0.84)	2.18 (0.84)	1.00 – 5.00
Overweight	3.39 (0.94)	3.21 (0.93)	3.29 (0.94)	1.00 – 5.00
Obese	4.11 (0.78)	3.85 (0.88)	3.97 (0.84)	1.00 – 5.00
Eight-angle Viewpoint Condition				
Underweight	1.62 (0.74)	1.70 (0.75)	1.67 (0.74)	1.00 – 4.00
Normal weight	2.16 (0.86)	2.19 (0.87)	2.17 (0.86)	1.00 – 5.00
Overweight	3.41 (0.93)	3.24 (0.93)	3.32 (0.93)	1.00 – 5.00
Obese	4.11 (0.82)	3.90 (0.87)	4.00 (0.85)	1.00 – 5.00

Spearman's Rank correlations were conducted to assess the relationship between the participant's weight loss rating and the BMI/BMI category of the stimuli (see Table 5.12). Significant positive relationships between weight loss ratings and stimulus BMI were found, suggesting that as BMI increased, the participant's agreement with whether they thought the person in the image should consider losing weight also increased ($p < .001$). The total number of observations were included for each correlation and are detailed on page 209, Section 5.5.3.

Table 5.12

The relationship between weight loss ratings and BMI/BMI category of the stimuli.

	Stimulus BMI			Stimulus BMI Category		
	All data	Two-angle	Eight-angle	All data	Two-angle	Eight-angle
Whole sample	.73***	.73***	.73***	.73***	.73***	.73***
Females	.71***	.71***	.71***	.71***	.70***	.71***
Males	.76***	.77***	.75***	.76***	.76***	.76***

*** $p < .001$, ** $p < .005$, * $p < .05$

There was a significant negative correlation between accuracy and weight loss ratings, indicating that increasing agreement with whether they thought the person in the image should lose weight was associated with decreases in the degree of accuracy (i.e. towards accuracy and/or the underestimation of BMI category). Spearman's Rank correlation coefficient and significance values are reported in Table 5.13. The number of observations for each correlation are detailed on page 209, Section 5.5.3.

Table 5.13

The relationship between weight loss ratings and accuracy of BMI category judgements.

	All data	Two-angle Condition	Eight-angle Condition
Whole Sample	-.26***	-.25***	-.28***
Females	-.26***	-.24***	-.28***
Males	-.27***	-.26***	-.27***

*** $p < .001$, ** $p < .005$, * $p < .05$

Next, Spearman's Rank correlations were conducted to investigate the relationship between weight loss ratings and participant characteristics/attitudinal measures for the whole sample and all observations (n = 10896). Spearman's Rank correlations revealed small significant positive correlations between weight loss ratings and ‘psych’ ($r_s = .07$, $p < .001$) and ‘fat attitudes’ ($r_s = .20$, $p < .001$). This indicates that increases in agreement that the person in the image should lose weight were associated with increases in body concerns/negative affect and anti-fat attitudes/athletic ideal internalisation. No significant correlations were found between weight loss ratings and the participant’s BMI or self-perceived weight status (ps > .05). There was a significant correlation between weight loss ratings and age ($r_s = .03$, $p = .003$), though this effect was very small.

Linear Mixed Effect Model of Attitudes to Weight Loss. The model for weight loss ratings was developed following the same procedure as for BMI category accuracy. It was determined that the inclusion of random intercepts for both participants and stimuli was warranted due to decreased AIC and BIC values and significant reductions in Log-Likelihood. For weight loss ratings, the inclusion of viewpoint did not result in a significant reduction in Log-Likelihood ($p = .572$), however, due to being a key aspect of the study’s methodological design, it was retained and included in the final model.

$$y_i = \beta_0 + \beta_1 x_1 * \beta_2 x_2 * \beta_3 x_3 * \beta_4 x_4 * \beta_5 x_5 + \mathrm{u}_{\mathrm{j}1} + \mathrm{u}_{\mathrm{j}2} + \epsilon_{i\mathrm{j}1\mathrm{j}2}$$

y_i = weight loss ratings, x_1 = stimulus BMI, x_2 = participant sex, x_3 = ‘psych’, x_4 = ‘fat attitudes’, x_5 = viewpoint, $\mathrm{u}_{\mathrm{j}1}$ = random intercept of the participant (participant ID), $\mathrm{u}_{\mathrm{j}2}$ = random intercept of the stimuli (stimulus ID), and $\epsilon_{i\mathrm{j}1\mathrm{j}2}$= residual error.

The final model explained approximately 85% of the variance in the data. A full summary of the model is presented in Appendix F.

There were significant Type III fixed effects of stimulus BMI ($F(1, 22) = 284.23$, $p < .001$), participant sex ($F(1, 5410) = 18.41$, $p < .001$) and ‘psych’ ($F(1, 5410) = 6.04$, $p = .014$) on weight loss ratings. There were significant two-way interactions between stimulus BMI and participant sex (F(1, 5410) = 14.15, p < .001), stimulus BMI and 'fat attitudes' (F(1, 5410) = 5.85, p = .016), participant sex and 'psych' (F(1, 5410) = 4.38, p = .037), and 'psych' and 'fat attitudes' (F(1, 5410) = 21.67, p = < .001). There were significant three-way interactions between stimulus BMI, 'psych' and 'fat attitudes' (F(1, 5410) = 27.99, p < .001), stimulus BMI, participant sex, and 'psych' (F(1, 5410) = 4.29, p = .038), and participant sex, 'psych' and 'fat attitudes' (F(1, 5410) = 6.01, p = .014).

As with the mixed model for accuracy, the significant four-way interaction for weight loss was explored using the same levels of BMI (minimum = 16.69, -1SD =18.57, mean = 25.09, +1SD = 31.62, maximum = 38.05) and 'psych'/'fat attitudes' (-1SD, mean, and +1SD).

There was a significant four-way interaction including stimulus BMI, participant sex, 'psych', and 'fat attitudes' (F(1, 5410) = 5.60, p = .018). As can be seen in Figure 5.6, weight loss ratings tended to increase with increasing BMI, indicating that people tended to agree that higher BMI bodies should lose weight but disagreed that lower BMI bodies should lose weight. Higher 'fat attitudes' (anti-fat attitudes/athletic ideal internalisation) produced the highest weight loss ratings across the BMI spectrum, stipulating higher agreement that the person in the image should lose weight. Pairwise comparisons between male and female weight loss ratings indicated significantly higher ratings from female observers for underweight/low-normal weight bodies, when 'fat attitudes' was at the mean level and when 'psych' was low or at mean level, and when 'fat attitudes' was high for all levels of 'psych' (p < .05). This indicates that females with higher psychological concerns were less likely to disagree that another female should consider losing weight, compared to men with the same levels of concerns. However, for low 'fat attitudes', there were no significant differences between male and female weight loss ratings at any level of ‘psych’, implying that attitudes to weight loss for low-normal BMI female bodies are similar irrespective of sex and body concerns/negative affect when anti-fat attitudes are low. For obese bodies, weight loss ratings were significantly higher for males than females when ‘fat attitudes’ was low and ‘psych’ was at the low mean and level ($p \leq .050$), indicating that men with lower bodyweight concerns were more likely to indicate that a female should consider losing weight, compared to females with the same concerns. As demonstrated in Figure 5.6 and Table 5.14, weight loss ratings tend to be higher for higher scores on both the ‘psych’ and ‘fat attitudes’ factors, suggesting that increased body concerns/negative affect and anti-fat attitudes are associated with a stronger agreement that a female should consider losing weight. All predicted means for weight loss ratings and pairwise comparisons of the difference between male and female weight loss ratings, for each level of BMI, ‘psych’, and ‘fat attitudes’ are presented in Table 5.14.

Figure 5.6

A plot of predicted weight loss ratings across the BMI spectrum, for each level of 'psych' (rows), 'fat attitudes' (columns), and observer sex (coloured lines).

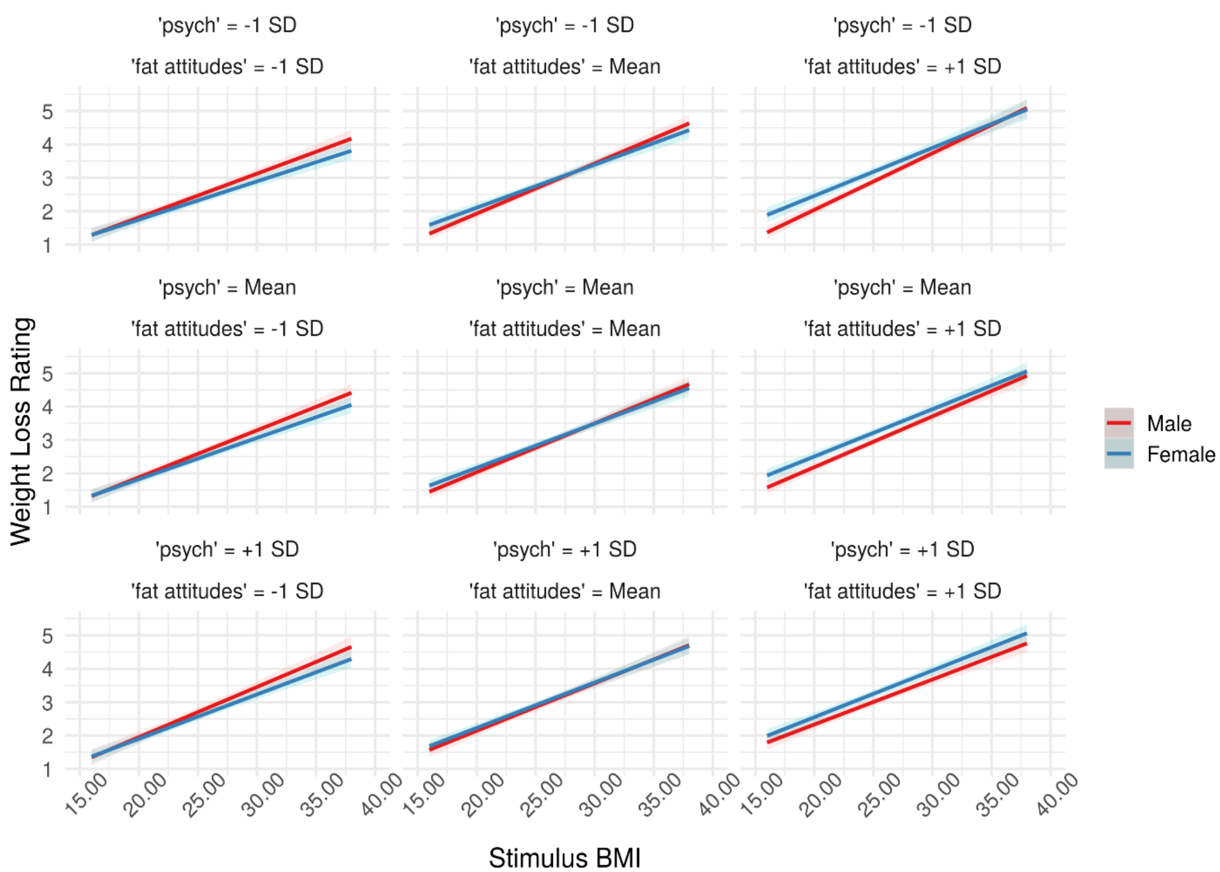


Table 5.14

Pairwise comparisons between male and female weight loss ratings, for each level of BMI, 'psych', and 'fat attitudes'.

	M_{Female}	M_{Male}	$M_{\text{Difference}}$	*SE*	*p*
		'fat attitudes' = -1SD			
'psych' = -1SD					
BMI 16.69	1.34	1.40	0.06	0.06	> .05
BMI 18.57	1.56	1.65	0.08	0.05	> .05
BMI 25.09	2.34	2.50	0.16	0.03	.005
BMI 31.62	3.12	3.35	0.23	0.05	.002
BMI 38.05	3.88	4.18	0.30	0.08	.050

	M_{Female}	M_{Male}	$M_{Difference}$	*SE*	*p*
'psych' = 0					
BMI 16.69	1.41	1.43	0.02	0.05	> .05
BMI 18.57	1.65	1.69	0.05	0.04	> .05
BMI 25.09	2.47	2.61	0.14	0.03	< .001
BMI 31.62	3.29	3.52	0.24	0.04	< .001
BMI 38.05	4.09	4.42	0.33	0.06	< .001
'psych' = +1SD					
BMI 16.69	1.48	1.46	-0.02	0.08	> .05
BMI 18.57	1.73	1.74	0.01	0.07	> .05
BMI 25.09	2.59	2.72	0.13	0.05	.050
BMI 31.62	3.46	3.70	0.24	0.06	.051
BMI 38.05	4.31	4.67	0.36	0.10	> .05
'fat attitudes' = Mean					
'psych' = -1SD					
BMI 16.69	1.67	1.45	-0.22	0.05	< .001
BMI 18.57	1.92	1.73	-0.19	0.04	.001
BMI 25.09	2.77	2.70	-0.07	0.03	> .05
BMI 31.62	3.62	3.67	0.05	0.04	> .05
BMI 38.05	4.47	4.63	0.16	0.06	> .05
'psych' = 0					
BMI 16.69	1.73	1.55	-0.18	0.03	< .001
BMI 18.57	1.98	1.83	-0.15	0.03	< .001
BMI 25.09	2.85	2.78	-0.07	0.02	> .05
BMI 31.62	3.72	3.74	0.02	0.03	> .05
BMI 38.05	4.58	4.69	0.10	0.05	> .05
'psych' = +1SD					
BMI 16.69	1.79	1.66	-0.13	0.05	> .05
BMI 18.57	2.04	1.93	-0.11	0.04	> .05
BMI 25.09	2.93	2.87	-0.06	0.03	> .05
BMI 31.62	3.82	3.81	-0.01	0.04	> .05
BMI 38.05	4.70	4.74	0.05	0.07	> .05
'fat attitudes' = +1SD					
'psych' = -1SD					
BMI 16.69	2.00	1.49	-0.51	0.07	< .001
BMI 18.57	2.27	1.81	-0.46	0.06	< .001
BMI 25.09	3.20	2.90	-0.30	0.04	< .001
BMI 31.62	4.13	4.00	-0.13	0.06	> .05
BMI 38.05	5.05	5.07	0.03	0.10	> .05
'psych' = 0					
BMI 16.69	2.05	1.67	-0.37	0.05	< .001
BMI 18.57	2.31	1.96	-0.35	0.04	< .001
BMI 25.09	3.23	2.96	-0.27	0.03	< .001
BMI 31.62	4.16	3.96	-0.20	0.04	.001
BMI 38.05	5.07	4.95	-0.12	0.07	> .05
'psych' = +1SD					

	M_{Female}	M_{Male}	$M_{\text{Difference}}$	*SE*	*p*
BMI 16.69	2.09	1.86	-0.23	0.06	.004
BMI 18.57	2.35	2.11	-0.24	0.05	.003
BMI 25.09	3.27	3.02	-0.25	0.04	< .001
BMI 31.62	4.19	3.93	-0.26	0.05	.001
BMI 38.05	5.09	4.82	-0.27	0.08	> .05

Overall, these findings indicate that views of whether a female should lose weight are influenced by the BMI of the body, with participants indicating stronger agreement that bodies with higher BMIs should lose weight and disagreement that lower BMI bodies should lose weight. This is modulated by the sex and attitudes (psychological concerns and anti-fat attitudes) of the observer. Those with higher attitudinal concerns tended to respond with higher agreement that the female in the image should lose weight. Females were more likely to agree that another female with an underweight to low-normal weight BMI should lose weight, particularly when the female (observer) had increased anti-fat attitudes/athletic ideal internalisation. For weight loss ratings, access to more visual information (i.e. viewing the body from 360-degrees at 45-degree intervals) did not have a significant effect on weight loss ratings, indicating that front-view and profile images of a female body provide enough information for a person to make a judgement of whether the female should lose weight.

5.6 Discussion

These findings support evidence for contraction bias as a common perceptual phenomenon which influences the accuracy of BMI category estimations of female bodies, using 3D scans varying in BMI from underweight to obese, in a sample of UK adults. This is consistent with previous research using a weight estimation task and front-view photographs of female bodies (Gledhill et al., 2019). These findings are also consistent with previous research using BMI category judgements, finding that obese female bodies are often underestimated by other adults (Oldham & Robinson, 2017). These results demonstrated that there was underestimation of approximately one BMI category for bodies in the obese class II category (BMI above 35), suggesting that those bodies are often visually perceived as overweight, which underestimates the severity of the obesity. Frequency data suggests that around two-thirds of responses underestimated obese bodies, mostly categorising as overweight and to a lesser extent a normal weight. The highest accuracy (over 87% of responses) was for bodies classified as a normal weight, suggesting that based on vision alone, men and women in the UK can identify a body that is a normal weight by WHO definition. Nevertheless, considering accuracy across the BMI spectrum, the majority of estimates were within one BMI category, indicating that most estimations were relatively accurate or under-/over- estimated by one category. Very few responses under-/over- estimated by two BMI categories. For example, for obese bodies, only 10% of responses underestimated by two BMI categories (i.e. identifying the body as a normal weight). Attitudes towards female bodies in the images suggest that agreement as to whether she should consider losing weight increased as the BMI of the bodies increased. There was, on average, agreement that obese female bodies should lose weight, whereas, on average, there was disagreement that underweight bodies should lose weight.

5.6.1 *Attitudes and Psychological Concerns*

For both accuracy and attitudes towards weight loss, there were modulating effects of attitudinal/psychological factors. In this research, two latent factors were found to represent attitudinal/psychological factors, i) ‘psych’ - body image concerns related to the self and negative affect, and ii) ‘fat attitudes’ - a combination of anti-fat attitudes and internalisation of an athletic ideal. The latent variable ‘psych’, used here, is consistent with previous research which also used PCA to create a latent factor representing attitudinal concerns relating to the individuals own body concerns/affect (e.g. Cornelissen et al., 2015; Irvine et al., 2020; Thaler et al., 2018). Interestingly, in this study, a second factor including anti-fat attitudes (dislike and will power subscales) and internalisation of an athletic physique was found, which relates to prejudice towards overweight people, a belief of personal controllability of weight, and a desire for an athletic body type.

Gledhill et al. (2019) found modulating effects of attitudinal concerns for the magnitude of weight under-/over-estimations in both Anorexia Nervosa and control participants, with slopes in line with that predicted by contraction bias. They report higher overestimation of lower BMI bodies for those with increased eating disorder beliefs scores. The findings presented here found significant overestimation of low BMI bodies for females, relative to men, when body concerns/negative affect were increased and when anti-fat attitudes were increased. This indicates that there are modulating effects of body concerns related to the self and general attitudes towards fatness, which may, in part, explain overestimation of low-normal weight same-sex bodies in women. Furthermore, these findings indicate the accuracy of obese and obese class II BMI categorisations were more accurate when body concerns and anti-fat attitudes were increased. This may be explained in that those with higher body concerns and fear of fatness may be more hyper-vigilant and display greater attentional biases towards bodies, this may result in a better ability to categorise bodies (i.e. an expertise effect), compared to those who have little concern for their own or others body weight. An ‘expertise effect’ has been proposed as an explanation for the increased ability of Anorexia Nervosa patients to discriminate between low BMI bodies, which may be a result of their increased viewing of and value placed on thin bodies (Cornelissen et al., 2017).

Attitudes towards weight loss in others were also modulated by psychological factors, such that lower body concerns/negative affect and anti-fat attitudes resulted in slightly lower ratings that the woman in the image should lose weight. This implies that generally having less concerns regarding body weight is associated with less agreement that another person should lose weight. On the other hand, those with higher anti-fat attitudes and internalisation of an athletic physique tend to respond with higher agreement that the female in the image should lose weight, which is a plausible discovery given the literature surrounding weight stigma discussed in the introduction (Section 1.4, Chapter 1). Together these results strongly indicate that attitudinal factors influence the perception of and attitudes toward female body size across the BMI spectrum.

5.6.2 *Observer Sex*

Previous research indicated inconsistent findings as to whether same-sex judgements of BMI categories were more accurate using male bodies (e.g. Oldham & Robinson, 2016; Robinson & Hogenkamp, 2015). Few studies have systematically investigated the influence of observer sex on the accuracy of BMI category judgements for female bodies. These findings reveal observer sex effects for both accuracy and weight loss attitudes, which interacted with attitudinal factors. Although, it must be acknowledged that mean accuracy differed between 0.10 and 0.20 units, which indicates that differences between sexes were small (less than a quarter of a BMI category). Males were slightly more accurate at making visual estimations of female BMI category, across the BMI spectrum, however, they were also more likely to agree that a higher BMI female should lose weight, compared to females, when they had lower attitudinal concerns. This evidence may relate to predictions from mate selection theory, in that men are sensitive to and select mates based on physical cues that signal health, fertility, youth, and the availability of resources to sustain pregnancy (Buss, 1989). One key cue is BMI (Singh, 2002; Tovée et al., 2002), indicating that accurate perception of body size is evolutionary advantageous as it promotes a mate selection strategy that favours reproductive success. Attitudes towards weight loss may also reflect these preferences towards a more attractive, healthy, and fertile BMI, as female bodies with moderate body fat tend to be rated as most attractive/healthy compared to those that are underweight or obese (Tovée et al., 2012).

For underweight to low-normal weight bodies, females were more likely to agree that another female should lose weight (particularly when they had average to increased anti-fat attitudes/athletic ideal internalisation). This is not surprising given the prevalence and value of the thin-ideal for women in Western societies and that females typically overestimated lower BMI bodies. These findings support the claim put forward by Robinson (2017), that the thin-ideal for women's bodies may have influenced the perception of underweight bodies as a normal weight and therefore that these women should lose weight. Together, these findings indicate that both observer sex and attitudinal/psychological concerns should be considered in future research investigating judgements of other people's bodies.

5.6.3 *Stimuli (Visual Information/3D Models)*

In this study, responses were compared when viewing bodies at two-angles or eight-angles, with the eight-angle presentation providing a 360-degree view of the body at 45-degree intervals. The eight-angle presentation enabled a greater understanding of the utility of including additional viewpoints, as an intermediate step to fully moveable/interactive 3D presentation (such as that in Virtual Reality [VR]). The results show that for BMI category accuracy, there were modulating effects of visual information as part of four-way interactions. There were no significant differences in mean accuracy (when controlling for attitudinal factors and sex), however, there were slight differences in the accuracy slopes between each viewpoint condition. Including extra visual information had little effect on BMI category accuracy, suggesting that there is no significant advantage of seeing the body from 360-degrees. For attitudes towards weight loss, there was no significant effect of viewpoint condition, suggesting that stimuli displaying front and profile viewpoints of a female body are enough for a judgement regarding whether the individual should lose weight and providing more visual information does not significantly influence these attitudes. This supports literature indicating that three-quarter/profile viewpoints capture the visual cues necessary for body size discrimination (Cornelissen et al., 2018) and a combination of frontal and profile viewpoints accurately capture a wide variety of anthropometric cues (Cohen et al., 2015; Rilling et al., 2009).

The patterns of findings reported here support previous studies using photographs of female bodies presented from either front-view or front- and profile-view (Gledhill et al., 2019; Oldham & Robinson, 2017), suggesting that the use of 3D body scans (with a photorealistic skin texture) is acceptable as stimuli in body size perception research and produces comparable results. This is helpful as 3D models can be presented in 2D in laboratory and online research, and 3D (life-sized/moveable) in VR environments, which enables these stimuli to be used in a variety of research settings. Recently, there has been a move towards the use of VR in body size perception research as it allows for a more immersive and ecologically valid experience (Ferrer-García & Gutiérrez-Maldonado, 2012). All things considered, it may be argued that there are no meaningful or significant benefits of including more viewpoints on accuracy or on attitudes to weight loss, so perhaps the extra visual information from VR or video footage may not be necessary in future work. Although, it also indicates that there may be no significant disadvantages of using methods where the full 360-degrees is visible - just that it is not necessary. However, it must be acknowledged that these findings do not consider the life-size and immersive elements of VR which may be beneficial due to increased resemblance with real life. Thaler et al. (2018) presented 3D life-sized female bodies, which were manipulated to increase and decrease in body weight by 20%, based on the individuals existing body shape/proportions. They found that self-estimates were inaccurate when using the female's own photographic identity, however, estimates using another identity were accurate. Other research using personalised 3D avatars in a self-perception task did not find any significant benefit of using an interactive, moveable VR representation of the body compared to 2D static versions of the same avatar (Hudson et al., 2020). Therefore, the investigation of judgements towards other adult's bodies presented life-sized and 3D in an immersive VR environment warrants further investigation in forthcoming research.

5.6.4 *Study Considerations*

In this study, categorical BMI labels were used to determine perceptions of weight status, a method which has been used in psychological research for categorising both the self and other female bodies (see e.g. Alkazemi et al., 2018; Atlantis & Ball, 2008; Hazzard et al., 2017; Oldham & Robinson, 2016, 2017). These verbal labels are commonly used in healthcare and epidemiological settings and may be more intuitively usable and well-understood by the general public, which enables insight into how these BMI category labels are perceived and whether they are perceived accurately by the UK general public. These findings support previous findings portraying deviations between the general public's perceptions of BMI categories and the actual health definitions (e.g. Crawford & Campbell, 1999; Donath, 2000). These findings suggest that around 50% of the time underweight bodies were categorised as a normal weight and around two-thirds of the time obese bodies were underestimated to be overweight, indicating that visual perceptions of these labels do not necessarily match WHO definitions. However, the responses were limited to the four main BMI categories (underweight, normal weight, overweight, and obese), so there was no possibility for participants to underestimate underweight or overestimate obese stimuli. This methodological limitation may have influenced and constrained the responses for these categories, as participants had to respond correctly or by overestimation (for underweight bodies) and underestimation (for obese bodies), resulting in the accuracy slopes that can be seen in these results. This means that even random responses may also produce a similar pattern of results. Moreover, attitudinal factors which decrease accuracy would result in the slope becoming steeper, such as decreased psychological concerns and fat attitudes observed in these findings. This must be taken into consideration when interpreting the findings from this study, to ensure that interpretation of these findings take into account that the pattern of findings may also reflect methodological constraints as opposed to purely capturing perceptual/attitudinal responses. Future work could provide two further labels e.g. 'emaciated' or 'extremely underweight, and 'severely obese', or use a scale reponse e.g. 0 – 100 (emaciated – obese) (see e.g. Gledhill et al., 2018; Moody et al., 2017), to allow overestimation or underestimation, or responses which are not constrained to the four given BMI categories.

Some of these verbal labels may have negative connotations or be considered stigmatising, for example, there is weight stigma associated with being obese or underweight (Swami et al., 2008; Swami et al., 2010). Truesdale and Stevens (2008) argue that people may be reluctant to categorise themselves as obese. This reluctance may extend to judgements of other people's bodies and may influence the likelihood of people using the extreme categories to categorise a body, despite anonymity and a lack of individual features in the stimuli. It has been suggested that underestimation of higher BMI bodies was greater when using verbal labels compared to body scales (Rietmeijer-Mentink et al., 2013) or self-reported height and weight (Truesdale & Stevens, 2008). This research found a strong correlation between self-reported BMI (from height and weight) and self-perceived weight status category, indicating that, at least for self-estimates, there was consistency between the two methods. Furthermore, consistencies between these current findings and previous research using numerical scales (such as Gledhill et al., 2019) demonstrate that there is clear evidence of contraction bias in perceptions of other female bodies even when using categorical verbal labels.

Moreover, this study used an online survey so that responses could be gained from a large sample of UK adults. Use of online surveys and data collection websites have been shown to return consistent results in a self-perception body size estimation task (Gardner et al., 2012) and is considered an acceptable methodological tool for psychological research (Gosling et al., 2004). However, the sample was predominately Caucasian, heterosexual, and aged 45 and below, which limits the generalisability of these findings to the general UK population. Likewise, the body stimuli used in this study were 3D body scans taken from Caucasian adults aged 45 and below and a Caucasian photographic texture was used. Future research may benefit from using more ethnically diverse and appropriate stimuli to further understanding about BMI categorisations and attitudes towards weight loss within and between different ethnic groups, given the real-life implications for clinical/healthcare settings and weight loss management. This may be achieved by collecting 3D body scans and anthropometric data from samples of females from different ethnic groups, since body fat distribution and BMI results in different body shapes for different ethnic groups (Misra & Khurana, 2011; Shiwaku et al., 2004; Wang et al., 1994; Wells et al., 2012).

To conclude, this research adds to the current body of literature indicating that obesity is visually underestimated in the UK population and that underweight bodies are often considered a normal weight, particularly by other females. Interestingly, it was found that opposite-sex judgements displayed slightly better accuracy across the BMI spectrum. Modulating effects of psychological and attitudinal factors on BMI category accuracy were found. Interactions between these two independent attitudinal constructs had different effects at different points along the BMI spectrum, indicating a complex relationship between attitudinal concerns, observer sex, and the BMI of the body being judged, on accuracy. Similarly, attitudes towards whether a female should lose weight also indicated a complex relationship involving attitudinal factors, the sex of the observer, and the BMI of the body. Although, generally, findings indicated that UK adults disagreed that underweight bodies should consider losing weight, but agreed that obese bodies should consider losing weight, particularly for male observers and those with higher anti-fat attitudes/internalisation of an athletic physique.

Chapter 6: (Studies 6 & 7) Beyond Body Mass Index - The Development and Validation of an Interactive Body Composition Scale Derived from 3D Scans

6.1 Introduction

As previously discussed (see Section 1.7, Chapter 1), many of the tools and techniques used in existing body image research tend to focus on a single dimension: Body Mass Index (BMI), which is often used as an index of body fat and as a marker of health risk associated with weight. Whilst BMI is generally a fast, cheap, and easy tool for estimating and monitoring a person's weight status and weight-related risks (Green, 2016; Hall & Cole, 2006), it can result in people being misclassified into incorrect categories for health/weight-related risks as it only considers total mass and does not distinguish between fat and fat-free mass (Romero-Corral et al., 2008). Using fat mass, rather than BMI, may result in more accurate classifications (Frankenfield et al., 2001; Gómez-Ambrosi et al., 2011; Hortobágyi et al., 1994; Okorodudu et al., 2010; Romero-Corral et al., 2008). Moreover, there are implications for research tools using bodies varying in BMI to investigate perceptions of body size/shape. A visual adaption study indicates that there are two dimensions of body shape (fat and muscle) which are perceived independently and encoded by separate neural mechanisms (Sturman et al., 2017). Additionally, muscle or 'lean mass' is denser than fat mass, so two people of the same weight (and BMI) may have different body compositions (levels of fat and muscle), and as a result, different body shapes (Mullie et al., 2008; Yajnik & Yudkin, 2004). This may result in inaccurate perceptions, for example, Groves et al. (2019) found that men's self-estimates of body size/shape were influenced by their own body composition and that of the stimuli, resulting in self-estimates that were prone to errors. This implies that to accurately capture body shape variation and self-estimates, consideration of both fat and muscle mass is necessary.

A variety of body scales have been created which incorporate variations of both fat and muscle mass (see Section 1.7, Chapter 1). However, there are some limitations in the ecological validity and realism of these existing scales, such as the use of line-drawings which are based on artistic impressions and the presentation of front-view only body stimuli. Furthermore, the most commonly used body composition scale (the Somatomorphic Matrix; Gruber et al., 1999) was not found to demonstrate sound test-retest reliability in men or women, so it may not be considered a reliable tool (Cafri et al., 2004; Kagawa, et al., 2006). A newer scale created using Computer-Generated Imagery (CGI) - the Visual Body Scale for Men (Talbot et al., 2019) - was based on replicating the hand-drawn figures from Cafri and Thompson's (2004) Modified Somatomorphic Matrix, consisting of two one-dimensional scales separately capturing muscularity and fat. This approach does not capture the interaction between the two dimensions, limiting its ability to accurately capture a person's perceived/ideal body composition (a specific combination of fat and muscle).

Two CGI scales were developed utilising combinations of fat and muscle rather than one-dimensional scales: The 'New Somatomorphic Matrix–Male' (Talbot et al., 2018) (created by emulating the Modified Somatomorphic Matrix) and 'The Body Image Matrix of Thinness and Muscularity – Male Bodies' (Arkenau et al., 2020). However, despite being an improvement on one-dimensional and line-drawing scales, they were not based on actual anthropometric data or any statistical calibration, which means the precision of the stimuli can be disputed and a direct comparison from the stimuli to the person's actual body composition is unlikely to be accurate. There is no female version of either scale. To date, a well-validated CGI body composition scale based on a statistical mapping to anthropometric data has not been created for women. Given the prominence and pertinence of the 'fit ideal' and muscularity concerns that women experience

(Cunningham et al., 2019; Garner, 1997; Gruber, 2007) and evidence indicating that fat and muscle have differential effects on judgements of attractiveness and health (Brierley et al., 2016; Lei & Perrett, 2020), where attractivess is driven specifically by lower fat but not muscle mass, there is still a need for an appropriate scale to be developed and validated.

One way to develop CGI stimuli is to use a combination of 3D scanning technology (which allows body shape to be captured accurately and for statistical mappings to anthropometric data to be made) and Principal Component Analysis (PCA) to predict 3D body shape along given dimensions. Some research has used a statistical BMI body model to investigate body perceptions by varying women's 3D scans +/- 20% from their actual BMI (e.g. Mölbert et al., 2018; Piryankova, Stefanucci et al., 2014; Thaler et al., 2018). However, the limited range in body size change may restrict the choices that a participant could potentially make, especially if estimates of ideal body size are to be gained, and fails to capture body composition variation. Moreover, the women's actual body size was the middle of the stimulus set with an equal number of increased/decreased body sizes on either side, which may have influenced responses if participants were biased towards the centre. Nonetheless, this research demonstrates the applicability of combining 3D scanning technology and PCA modelling in perceptual body image research. Although, at the time of developing this research, no model for body composition (fat and muscle) had been developed, validated, or used in perceptual body image research.

In this chapter, the development of a novel statistical body model (for women), using PCA to predict 3D shape from fat and skeletal muscle mass has been described (based on the database of 3D body scans and composition data described in Section 2.4, Chapter 2). In Study 6, the plausibility of the body model was explored using a rating task. In Study 7, an interactive body composition scale was developed from the model, using a method adjustment paradigm to manipulate a female 3D body shape along the two dimensions. The psychometric properties (reliability and validity) of the scale were evaluated and estimates of perceived and ideal female body composition were gathered, to determine whether it may be a useful tool for future assessment of perceptual body image and body composition ideals.

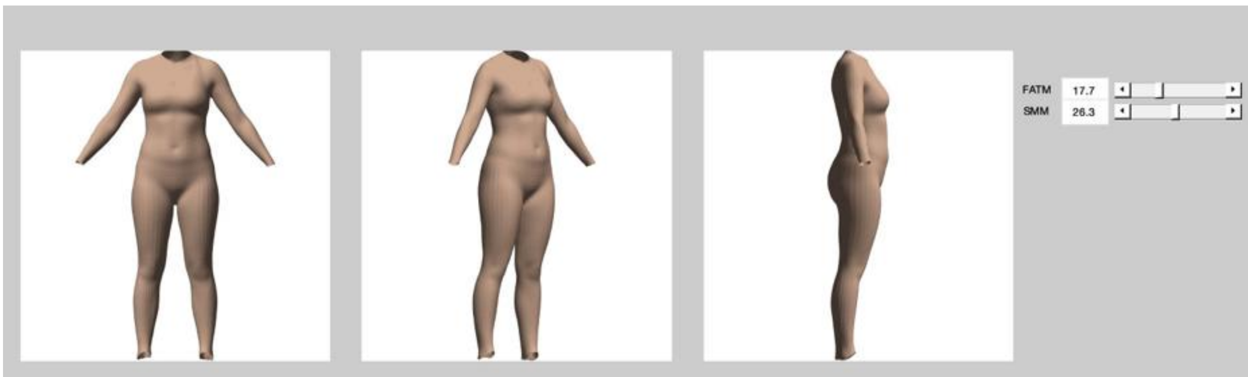
6.2 Stimuli Creation: A Statistical Model of 3D Shape, Predicted by Fat and Skeletal Muscle Mass

The 3D body scan and composition data from 221 Caucasian women aged 18-45 years old (described in detail in Section 2.4, Chapter 2) were used to develop a statistical mapping between 3D shape and fat mass (FATM) and skeletal muscle mass (SMM). For this analysis, the processed 3D shapes (meshes) for each female and their FATM and SMM (both in kgs) were considered.

The data were analysed using a PCA performed in Matlab 2018a (The MathWorks Inc., 2018). When running a PCA on the processed meshes, there was a large proportion of variance coming from postural and positional factors that were unrelated to body size/shape, which was the primary focus of this analysis. Therefore, to reduce this 'noise', the following techniques were used to further prepare the 3D meshes for data analysis. In its simplest form, a 3D mesh is a point cloud which consists of a set of points with three [X, Y, Z] coordinates per point and the collection of these points represent the 3D object (in this scenario; a human body). First, the coordinates associated with points referring to heads, necks, hands, and feet were removed from each mesh as they contributed irrelevant noise/variability. Second, the average 3D shape for the set was calculated, and all individual meshes were fitted to this average using a partial Procrustes fit (translation and orthogonal rotation only). This allowed for the 3D meshes to be aligned as closely as possible, minimising the variance from posture and body position, whilst maintaining individual variability in size/shape. Figure 6.1 shows a visualisation of the average 3D shape, rounded to the nearest decimal place (M_{Fat} = 17.65, M_{SMM} = 26.34).

Figure 6.1

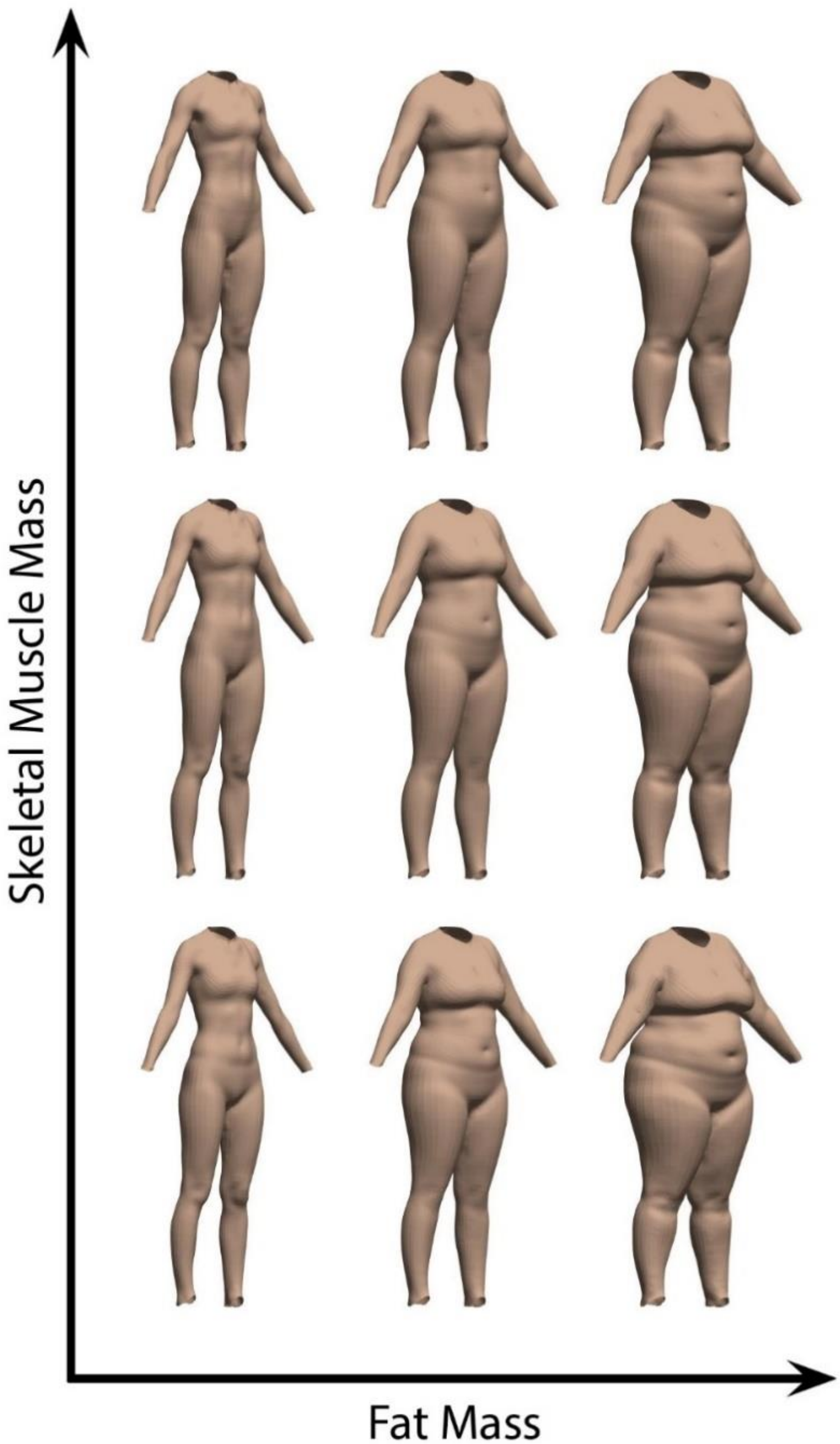
Visualisation of the average 3D body shape from three different viewpoints.



Therefore, each 3D mesh was converted to a vector of 79,995 numbers (26,665 points x 3 coordinates), with this vector being used in the PCA. Next, for each component produced from the PCA, linear regressions were conducted using the values of FATM and SMM associated with each scan as predictors. No components were removed to retain as much information as possible. Using the coefficients and constant from the regression models, the predicted location on each component enabled the prediction of and ultimately the visualisation of 3D shape at any given FATM and SMM value. For this research, we focused on predictions within the limits of actual values collected in the database so that the shapes were based on actual anthropometric data. Figure 6.2 displays visualisations of predicted 3D shapes, within the limits of our actual sample (minimum FATM = 4.20, minimum SMM = 18.90, maximum FATM = 52.90, maximum SMM = 35.10; full descriptive statistics can be found in Section 2.4, Chapter 2).

Figure 6.2

Visualisations of predicted shapes at three different levels (minimum, median, and maximum) of the range of fat and skeletal muscle mass values represented in this sample.



Study 6: The Plausibility of Body Composition Manipulations in The Statistical Model.

To identify whether the FATM and SMM manipulations from the statistical body model were plausibly capturing changes in body composition that could be perceived, we employed a rating task where images of the predicted shapes were exported at different combinations of FATM and SMM. Each image was rated for its level of fat and muscle, so that we could identify correspondences between the ratings of the shapes fat/muscle with the FATM/SMM of the body shape in the image.

6.3 Method

Ethical approval was gained from the University of Lincoln Research Ethics Committee (Project code: 0908).

6.3.1 *Participants*

A total of 65 participants aged 18 - 45 years old (31 males, M_{age} = 28.90, *SD* = 7.55, and 34 females, M_{age} = 23.79, *SD* = 6.03) were recruited through opportunity sampling (e.g. posts on social media websites, word-of-mouth and posters around the University of Lincoln), Prolific online participant recruitment website, and through recruitment of undergraduate students in return for course credits. Prolific respondents were rewarded £1.67 for participation. The majority of the sample identified as heterosexual (81.54%). The remainder of the sample identified as bisexual (13.85%), homosexual (1.54%), pansexual (1.54%) or selected the prefer not to say option (1.54%). The sample was mostly Caucasian (84.62%), with 12.31% non-Caucasian, and 3.08% unknown.

6.3.2 *Materials*

Body Stimuli. To check the plausibility of the fat and muscle slider manipulations, images taken from the statistical model of body composition were used. The model was based on 3D body scans and body composition measurements (FATM and SMM in kg) taken from 221 Caucasian females aged 18 - 45. A combination of PCA and linear regressions allowed the prediction of 3D body shapes from FATM and SMM values (more details can be found in Section 6.2). Images of the predicted body shapes were taken at 10 levels of FATM, in equal steps of 5.40 units from the minimum to the maximum. For each level of fat, images were taken at five levels of SMM as there was less variance in muscle mass in our database, which were equally spaced 4.00 units apart (see Table 6.1). This resulted in a total of 50 images. In each image, the 3D body shape was presented at three different angles (front-view, profile, and three-quarters) simultaneously. An example is presented in Figure 6.3.

Table 6.1

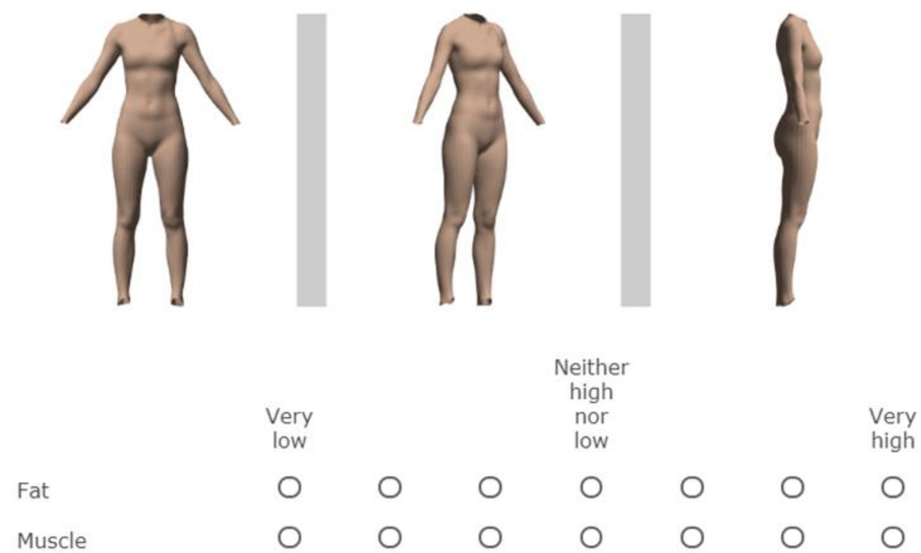
Levels of fat and muscle used for stimuli generation, with the associated fat and skeletal muscle mass values in kg.

Level	Fat Mass	Skeletal Muscle Mass
1	4.20	19.00
2	9.60	23.00
3	15.00	27.00
4	20.40	31.00
5	25.80	35.00
6	31.30	
7	36.70	
8	42.10	
9	47.50	
10	52.90	

Stimulus rating task. There were two 7-point rating scales from 'very low' to 'very high' with the labels 'fat' and 'muscle' to assess the perceived adiposity (fat) and muscularity of the body shapes (Figure 6.3). Participants were instructed to rate each image for their level of fat and muscle using the scales displayed below each image and to use the full range of the scale when making their judgements. All stimuli were presented in random order.

Figure 6.3

Example of a body stimulus with rating scales, as presented to participants in the Qualtrics form.



6.4 Procedure

Participants completed this study online via Qualtrics using a computer or laptop. After providing informed consent, they were asked to complete some demographic questions (sex, age, ethnicity, sexual orientation, and current diagnosis or history of an eating/body image disorder). Next, they were presented with the body stimuli in a random order, which were each rated using the 'fat' and 'muscle' rating scales displayed below the image, resulting in a total of 100 ratings for the 50 images. This was a fully crossed design, so all images were rated by all participants for both fat and muscle. Once completed, they were presented with a written debrief form. The whole procedure took approximately 20 minutes.

6.5 Data Analysis

All analyses were conducted using R Studio (R Version 3.6.0). The relationship between responses on the rating scales and the actual FATM/SMM values associated with the image from the statistical body model were analysed using Spearman's Rank correlations. Interrater reliability was calculated using the icc function from the irr package (Version 0.84.1; Gamer, 2012). Interrater agreement for single-item measures was calculated using the rwg function from the multilevel package (Version 2.6; Bliese, 2016). Analyses were conducted separately for fat and muscle and were conducted for the whole sample, then for male and female participants separately.

6.6 Results

6.6.1 *Descriptive Statistics.*

The mean response on the fat rating scale was 4.54 (SD = 1.78) and the median was 5.00. Participants used the full range of the rating scale (min = 1, max = 7). The mean response on the muscle rating scale was slightly lower (M = 3.39, SD = 1.49), as was the median (3.00). The full range of the muscle rating scale was also used (min = 1, max = 7).

There was a significant negative correlation between ratings of fat and muscle, such that as the ratings of fat increased, the ratings of muscle tended to decrease ($r_s = -.55$, $p < .001$). This was similar for male ($r_s = -.55$, $p < .001$) and female ($r_s = -.54$, $p < .001$) observers. Table 6.2

displays the average fat and muscle rating for each level of fat mass and Figure 6.4 displays the mean fat and muscle rating for each level of fat and muscle mass.

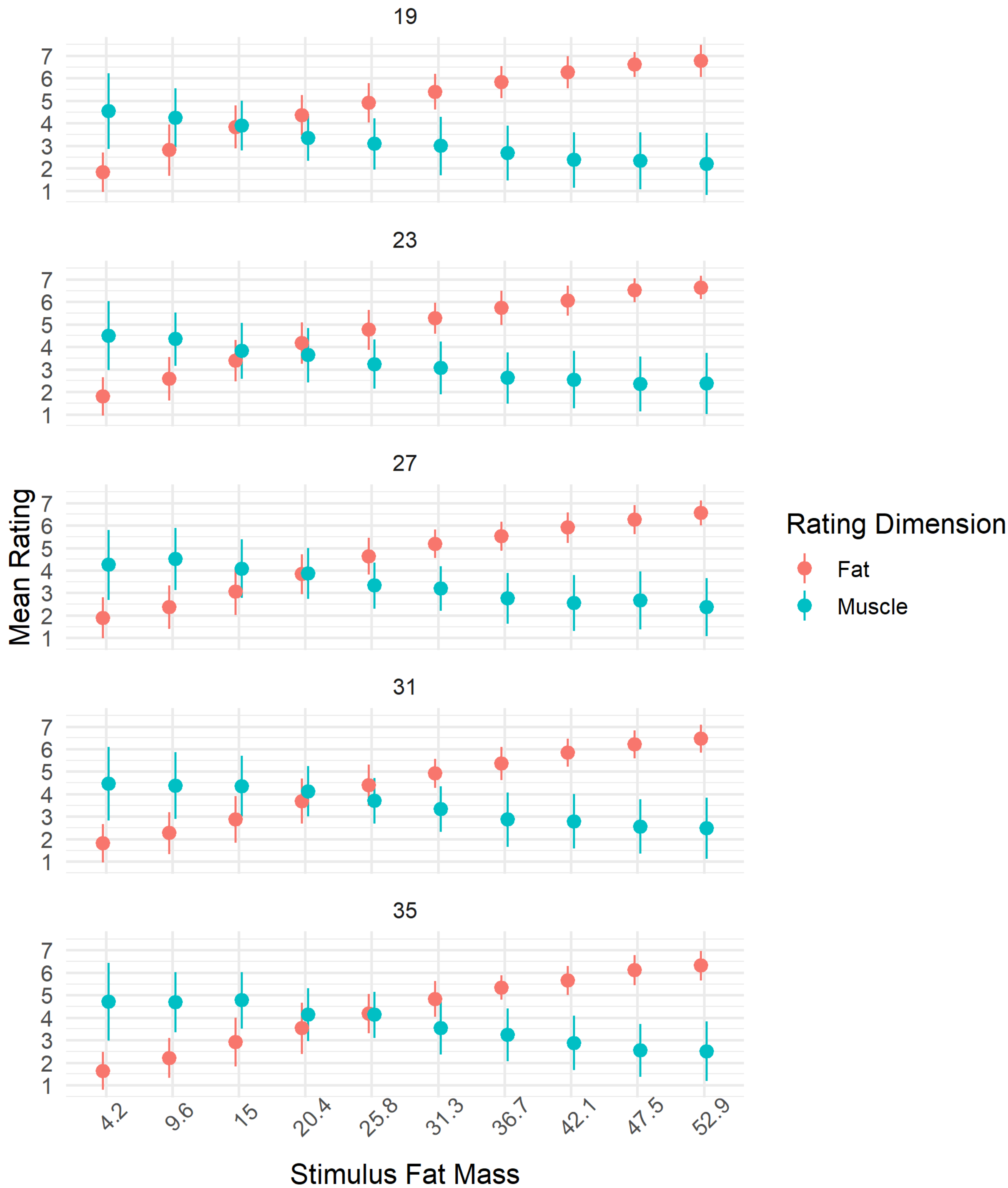
Table 6.2

The mean and standard deviation of the muscle and fat ratings for each level of stimulus fat mass, for the whole sample and each sex.

	Whole sample (n = 65)		Males (n = 31)		Females (n = 34)	
Stimulus FATM	Fat	Muscle	Fat	Muscle	Fat	Muscle
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
4.20	1.79 (0.86)	4.49 (1.62)	1.82 (0.80)	4.56 (1.47)	1.77 (0.92)	4.42 (1.75)
9.60	2.44 (1.00)	4.43 (1.34)	2.42 (0.92)	4.54 (1.28)	2.46 (1.06)	4.33 (1.39)
15.00	3.21 (1.07)	4.18 (1.30)	3.23 (1.01)	4.23 (1.28)	3.19 (1.12)	4.14 (1.32)
20.40	3.91 (1.02)	3.82 (1.17)	3.95 (0.97)	3.85 (1.18)	3.87 (1.06)	3.79 (1.16)
25.80	4.57 (0.91)	3.49 (1.12)	4.62 (0.93)	3.55 (1.19)	4.52 (0.89)	3.43 (1.05)
31.30	5.12 (0.74)	3.22 (1.14)	5.12 (0.80)	3.29 (1.13)	5.12 (0.69)	3.15 (1.15)
36.70	5.56 (0.71)	2.83 (1.19)	5.60 (0.74)	2.87 (1.22)	5.52 (0.67)	2.79 (1.16)
42.10	5.94 (0.69)	2.62 (1.24)	6.00 (0.70)	2.68 (1.30)	5.89 (0.68)	2.57 (1.19)
47.50	6.34 (0.63)	2.49 (1.23)	6.36 (0.62)	2.57 (1.29)	6.31 (0.64)	2.41 (1.17)
52.90	6.54 (0.63)	2.38 (1.34)	6.55 (0.67)	2.57 (1.46)	6.54 (0.61)	2.21 (1.20)

Figure 6.4

Mean and standard deviation of fat and muscle ratings for each level of fat mass (x-axis) and each level of muscle mass (rows).



6.6.2 *The Relationship Between Ratings and Body Composition of the Predicted 3D Shape.*

For the correlations, the total number of observations for each participant (n = 65) and each stimulus (n = 50) were included, meaning that the total number of observations was 3250 for all participants, 1700 for females, and 1550 for males. There was a significant positive correlation between fat ratings and the FATM of the stimuli ($r_s = .89$, $p < .001$). This relationship was significant and positive for both male ($r_s = .88$, $p < .001$) and female ($r_s = .89$, $p < .001$) participants. This indicates that ratings of fat mass increased as the fat mass of the stimulus increased. Similarly, for muscle mass, there was a significant positive correlation between muscle ratings and the SMM of the stimulus, for the whole sample ($r_s = .13$, $p < .001$). This relationship was significant and positive for both male ($r_s = .12$, $p < .001$) and female ($r_s = .14$, $p < .001$) participants. This indicates that ratings of muscle mass increased as the SMM of the stimulus increased.

Partial Spearman's Rank correlations were conducted to look at the relationship between fat ratings and stimulus FATM while controlling for muscle ratings. There was a significant positive correlation for the whole sample ($r_s = .84$, $p < .001$) and for both male ($r_s = .84$, $p < .001$) and female ($r_s = .84$, $p < .001$) participants. Similarly, the relationship between muscle ratings and stimulus SMM remained significant when controlling for fat ratings ($r_s = .07$, $p < .001$). This was significant and positive for both male ($r_s = .07$, $p = .004$) and female ($r_s = .08$, $p = .002$) participants. These correlations were small, indicating that there was a weak relationship between perceived muscle and the SMM of the stimuli when controlling for perceived fat mass.

Interrater Reliability. Two-way random, consistency, average-measures intraclass correlations were used to assess the degree of consistency in ratings of fat/muscle across the stimuli. The results are presented in Table 6.3. The Intraclass Correlation Coefficients (ICCs) were high, for both fat and muscle ratings, and exceed the 0.70 and 0.80 criteria put forward by Nunnally (1978) and Carmines (1990). This is indicative of excellent interrater consistency among ratings.

Table 6.3

Intraclass Correlation Coefficients, 95% confidence intervals and significance values for fat and muscle ratings, for the whole sample and each sex.

	Whole sample (n = 65)		Males (n = 31)		Females (n = 34)	
Ratings	ICC	95% CI	ICC	95% CI	ICC	95% CI
Fat	.997***	.996 - .998	.994***	.991 - .996	.994***	.992 - .996
Muscle	.975***	.964 - .984	.942***	.916 - .963	.957***	.937 - .972

*** $p < .001$, ** $p < .005$, * $p < .05$

Interrater agreement for each stimulus was calculated using r_{wg} (James et al., 1984, 1993). The mean r_{wg} value for fat ratings was 0.84 (range: 0.68 – 0.93), indicating good agreement overall (M_{male} = .84, M_{female} = .83). The mean r_{wg} for muscle ratings was 0.60 (range 0.26 – 0.76), indicating reasonable agreement overall (M_{male} = .59, M_{female} = .61). The r_{wg} values for each stimulus (level of fat and muscle) are displayed in Appendix G (Tables G.1 and G.2, for fat and muscle ratings, respectively).

Summary of Results

These findings suggest that the body composition manipulations from the statistical model were being perceived as intended, in that as the FATM/SMM of the predicted 3D shapes increased, the ratings of perceived fat/muscle mass also increased. There was a significant, negative relationship between ratings on each scale, such that muscle mass ratings decreased as fat mass ratings increased, which may be expected as muscle mass is more visible when fat mass is lower. The relationship between fat ratings and stimulus fat mass was strong, even when controlling for ratings of muscle, demonstrating evidence of the plausibility of the fat mass manipulation. For muscle mass, the relationship between ratings and actual SMM was significant but weak and was weakened when controlling for fat ratings. This may be attributed, at least in part, to the fairly limited range and visibility of muscle mass in females, as can be seen in Figure 6.2. On average, interrater consistency was high, and agreement was good for the fat ratings and reasonable for the muscle ratings. This indicates that the ratings were generally consistent and in agreement across participants. Next, using this body composition model, the construct validity and test-retest reliability of perceived current, ideal, and ideal partner body composition estimates was assessed, to further examine the psychometric properties for use in future perceptual body image research.

Study 7: The Psychometric Properties of a Novel Interactive Body Composition Scale for Assessment of Female Body Composition Perceptions and Ideals.

6.7 Method

Ethical approval was gained from the University of Lincoln Research Ethics Committee (Project code: 0908).

6.7.1 *Aims*

The main aims of this study were to assess the psychometric properties (construct validity and test-retest reliability) of a novel interactive body composition scale (derived from the statistical body model) and to investigate perceived and ideal female body composition (measured by women's self-estimates of their perceived current and ideal and men's estimates of their ideal female partner).

6.7.2 *Participants*

Responses from participants who identified as having a current or history of an eating/body image disorder (n_{female} = 1 and n_{male} = 1) or their sexual orientation as 'homosexual' or 'in another way' (n_{female} = 2 and n_{male} = 3) were excluded. This resulted in a final sample of 30 females and 21 males (cis-gender/as assigned at birth) aged 18 - 45 years old, (M_{female} = 19.97, SD = 1.52; M_{male} = 20.52, SD = 1.54) recruited from the University of Lincoln. Undergraduate psychology students received course credits for participation. The majority of the sample identified as heterosexual (86.67% of women and 95.24% of men). The remainder of the sample identified as bisexual (10.00% of women and 4.76% of men) or selected the 'prefer not to say' option (3.33% of women and 0.00% of men). The sample mostly identified as Caucasian

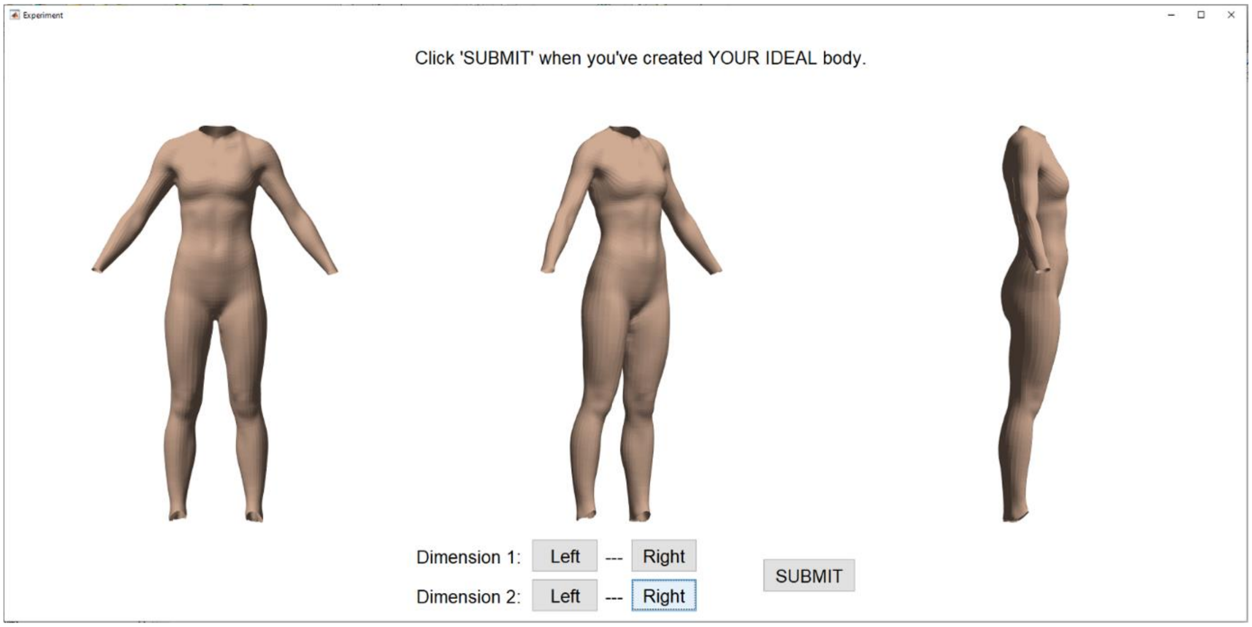
(86.67% of women and 90.48% of men). There were 13.33% of women and 4.76% of men that were non-Caucasian, and 4.76% of men that were unknown/undisclosed.

6.7.3 *Materials*

Interactive Body Composition Scale. The interactive body composition scale was created using the statistical model described in Section 6.2. In this experiment, the users were able to manipulate the predicted 3D body shape along the two body composition dimensions (FATM and SMM). The dimensions were labelled ‘Dimension 1’ and ‘Dimension 2’ which corresponded to changes in FATM and SMM respectively, so that participants were not aware of what body composition dimension/s were being manipulated. To manipulate the predicted 3D body shape there were ‘left’ and ‘right’ buttons for each dimension. The direction of the ‘left’ and ‘right’ buttons was randomised to either increase or decrease the dimension, this was to control for directional preferences/biases and memory from influencing responses. The predicted 3D body shape changed in real-time, in a continuous manner (steps of 1 kg). The 3D shapes were displayed from three different angles (front, profile, and three-quarters) simultaneously on a white background. An example of the user interface is presented in Figure 6.5.

Figure 6.5

A screenshot of the interactive body composition scale, as displayed to participants.



Body Estimations. Using the interactive body composition scale, participants were asked to create three body estimations representing their; i) perceived current - the body size/shape closest to how they looked at the time, ii) ideal body - the body size/shape they would ideally like to have, and iii) ideal partner - the body size/shape representing how they would ideally like their partner to look. The order of estimations was randomised. Each estimation was made twice, immediately after one another, and the FATM and SMM values for each estimation was recorded. For each body estimation, the average of the two FATM and SMM values was calculated and used in analyses. The predicted shape for each estimation started at random FATM and SMM values. To assess the test-retest reliability, the same estimations were completed again two or three days later.

Psychometrics. The psychometric measures outlined in Section 2.2, Chapter 2 were used in this study to assess body image, eating disorder psychopathology, self-esteem, depression, and internalisation of body ideals. In addition, a questionnaire used to assess drive for muscularity was included (described below).

Drive for Muscularity Scale (DMS; McCreary & Sasse, 2000). The DMS is a 15-item questionnaire assessing a person's desire for a muscular body. This includes questions relating to a persons' muscle-oriented attitudes (i.e., "I wish that I were more muscular") and muscle-oriented behaviours (i.e., "I lift weights to build up muscle"). It has demonstrated good validity and reliability in both men and women (McCreary, 2007). The items are answered on a 6-point scale from 'always' to 'never'. All items are reversed coded so that a higher score indicates a higher drive for muscularity. A global drive for muscularity score, calculated by averaging answers on each item, is calculated for both men and women. Additionally, separate muscle-oriented attitudes and behaviour subscales may be calculated for men by averaging responses for the muscle-oriented attitudes and behaviours questions pertaining to each scale (McCreary et al., 2004).

For BSQ, EDE-Q Global, RSE, BDI, SATAQ-4 Thin Ideal Internalisation, SATAQ-4 Athletic Ideal Internalisation, and DMS global, Cronbach's alpha was .93, .92, .93, .87, .74, .93, .92, respectively.

Body Measurements. Body composition measurements were taken using the Tanita BIA scale, as outlined in Section 2.1, Chapter 2.

6.8 Procedure

Firstly, after providing informed consent, participants filled in demographic information using a Qualtrics form (sex, ethnicity, age, history or current diagnosis of an eating disorder, and sexual orientation). Next, the body estimation tasks were completed using the interactive body composition scale. Afterwards, psychometric measures were completed using a Qualtrics form. These tasks were completed on a 21.5" flat-panel LCD screen with a resolution of 1920 x 1080 pixels in a university lab. Lastly, body measurements were taken. At the follow-up session, two or three days after initial testing, participants were asked to complete the body estimation tasks again before being debriefed.

6.9 Data Analysis

Analyses were conducted using ‘R Studio’ (R Version 4.0.2). From the interactive body composition scale, the average of the two FATM and SMM values for each of the body estimations was used. Additionally, for each body estimation, two new body estimation variables were calculated: i) Body Image Distortion (BID; the difference between the participant’s perceived and actual body composition) was calculated by subtracting actual body composition from perceived current body composition. A negative value indicates underestimation of fat/muscle, 0 indicates complete accuracy, and a positive value indicates overestimation of fat/muscle, and ii) Perceptual Body Dissatisfaction (BD; the difference between the participant’s ideal and perceived body composition) was calculated by subtracting perceived current body composition from ideal body composition. A negative value indicates a desire for decreased fat/muscle relative to perceived current, 0 indicates no difference between ideal and perceived current, and a positive value indicates a desire for an increased fat/muscle relative to perceived current. These variables were calculated separately for fat and muscle and for each session.

For this analysis, the focus was on perceptions of female body size/shape, this includes the women's self-estimates of perceived current and ideal body size/shape and the men's ideal (female) partner body size/shape, such that reporting of 'ideal partner' refers to men's ideal female partner.

For variables where the assumption of normality was violated, determined using Shapiro-Wilk tests (*p*s < .05), non-parametric alternatives of statistical tests were used. The variables that were not normally distributed included the women's actual fat mass, ideal fat mass in session 1, perceived fat mass in session 2, BID muscle in session 2, the men's ideal partner fat estimations in session 2.

6.10 Results

6.10.1 *Participant Characteristics*

Table 6.4 presents participant characteristics, including age, BMI, and body composition (fat and SMM in kg), for women (n = 30) and men (n = 21) separately. When looking at the sample distribution according to BMI category, of the women, four were underweight (13.33%), 22 were a normal weight (73.33%), three were overweight (10%) and one was obese (0.33%). Of the men, three were underweight (14.29%), 14 were normal weight (66.67%), four were overweight (19.05%) and none were obese. There was a 100% retest rate, in that all participants completed both session 1 and session 2.

Table 6.4

Descriptive statistics (mean, standard deviation, minimum and maximum) of the participant's characteristics.

	Females (n = 30)				Males (n = 21)			
Participant Characteristic	*M*	SD	Min	Max	*M*	SD	Min	Max
Age	19.97	1.52	19.00	26.00	20.52	1.54	19.00	25.00
BMI	21.72	3.48	15.40	33.20	22.18	3.02	16.60	27.40
Fat Mass	15.81	6.59	5.70	38.90	12.00	5.76	3.40	26.90
SMM	24.76	2.71	18.90	31.20	34.87	3.83	26.40	41.90

Abbreviation. SMM = Skeletal Muscle Mass (kg).

For the female sample, fat mass was significantly strongly correlated with BMI ($r_s = .87$, $p < .001$) and moderately correlated with SMM ($r_s = .41$, $p = .025$). Similarly, BMI and SMM were positively correlated ($r = .67$, $p < .001$). For the male sample, there were significant correlations between fat mass and BMI ($r = .86$, $p < .001$) and SMM and BMI ($r = .67$, $p < .001$). There was no significant correlation between fat mass and SMM ($r = .38$, $p > .05$).

6.10.2 *Psychometric Measures*

Descriptive statistics for psychometric data obtained in session is presented in Table 6.5 for men and women separately. Shapiro-Wilks tests for each of the psychometric measures indicated that EDE-Q scores (all subscales and global) for the female sample, and EDE-Q Restraint and Eating Concern subscales for the male sample violated assumptions of normality (*p*s < .05). Details regarding relationships between psychometric measures and with body measurements can be found in Appendix H. In Chapters 3 and 5, Principal Component Analysis was employed to determine latent factor/s, but this was not conducted here as the relationships between body estimations and specific measures of attitudinal and psychological concerns were important to identify, for validation purposes. As in Study 4, some unique relationships between body estimations and each psychometric measure may occur. At this stage, it is important to determine which exact measures are related to body composition estimations using this novel body scale.

Table 6.5

Descriptive statistics (mean, standard deviation, minimum, and maximum) for each psychometric measure.

	Females (n = 30)			Males (n = 21)		
Psychometric Measure	*M*	SD	Min – Max	*M*	SD	Min – Max
EDE-Q Dietary Restraint	1.09	1.10	0.00 – 4.00	0.84	0.85	0.00 – 2.80
EDE-Q Eating Concerns	0.76	0.83	0.00 – 2.80	0.44	0.63	0.00 – 2.40
EDE-Q Shape Concerns	2.11	1.48	0.12 – 4.62	1.40	0.98	0.00 – 3.00
EDE-Q Weight Concerns	1.77	1.42	0.20 – 4.20	1.10	0.87	0.00 – 3.20
EDE-Q Global	1.43	1.07	0.08 – 3.46	0.95	0.61	0.00 – 2.54
RSES Total	17.83	6.19	8.00 – 30.00	20.33	5.68	7.00 – 30.00
BDI Total	12.20	8.72	0.00 – 32.00	8.14	4.62	0.00 – 20.00
BSQ Total	40.33	15.70	17.00 – 71.00	31.29	9.48	17.00 – 50.00
Thin Ideal Internalisation	3.15	0.88	1.00 – 4.60	2.88	0.89	1.40 – 5.00
Athletic Ideal Internalisation	2.99	1.18	1.20 – 5.00	3.44	1.10	1.20 – 5.00
Drive for Muscularity Total	2.27	0.75	1.00 – 3.93	3.23	1.10	1.40 – 5.00

6.10.3 *Body Estimations*

The descriptive statistics of each body estimation from session 1 are presented in Table 6.6. Participants tended to use the full range of the muscle dimension (actual range: 18.90 – 35.10) whereas, for the fat dimension participants tended to use the lower end, particularly when creating their ideal body size/shape, indicating a desire for a lower fat mass (actual range: 4.20 –

52.90). On average, the ideal fat was around 8.58kg and the maximum was 18.05kg, despite the participant's actual fat mass reaching 38.90kg. The women tended to underestimate their fat mass (BID fat) and desire a lower fat mass than their perceived (BD fat), demonstrated by the negative means. One sample t-tests indicated that both BID fat and BD fat were significantly different from 0 (where 0 indicates no difference) for both sessions (ps < .05), suggesting a significant underestimation of fat and desire for lower fat compared to perceived. Participants tended to slightly overestimate their muscle mass (approximately 1.75kg on average) and their ideal was similar to their perceived (increase of 0.30kg on average). One sample t-tests indicated that BID muscle was significantly higher than 0 for both sessions (ps < .05), whereas BD muscle was not significantly different to 0 (ps > .05), suggesting significant overestimation of muscle mass but no difference between perceived and ideal muscle mass.

Table 6.6

Descriptive statistics (mean, standard deviation, minimum, and maximum) of body estimations from the first session.

Body Estimation	*M*	SD	Min	Max
	Fat			
Perceived	11.43	5.27	4.55	25.55
Ideal	8.58	4.42	4.20	18.05
BID	-4.39	5.44	-15.85	7.20
BD	-2.84	5.08	-11.00	12.15
Ideal partner	11.05	5.25	4.20	37.20
	Muscle			
Perceived	26.51	3.50	19.50	33.50
Ideal	26.81	4.12	19.50	34.10
BID	1.75	3.96	-6.75	7.90
BD	0.30	5.14	-14.00	8.00

Body Estimation	*M*	SD	Min	Max
Ideal partner	26.92	3.55	20.50	33.00

The Relationship Between Fat and Muscle. To identify whether there were any associations between fat and muscle for each estimation, correlations between the FATM and SMM values of each body estimation were conducted. There was no significant relationship between fat and muscle selections for perceived current (Session 1, $r_s = -.15$, $p > .05$; Session 2, $r_s = .05$, $p > .05$), ideal (Session 1, $r_s = -.34$, $p > .05$; Session 2, $r_s = -.25$, $p > .05$), or ideal partner (Session 1, $r_s = .29$, $p > .05$; Session 2, $r_s = -.13$, $p > .05$) body estimations. This indicates that the FATM and SMM of the body estimations using the interactive body composition scale were independent and not systematically associated, therefore subsequent analyses were conducted for fat and muscle separately.

The Relationship Between Body Estimates and Actual Body Size/Composition. The participant's perceived fat mass significantly correlated with both BMI and actual fat mass (*p*s < .05), whereas perceived muscle mass did not correlate with actual body size/composition (actual BMI, fat mass, or SMM; *p*s > .05). See Construct Validity section for coefficient values.

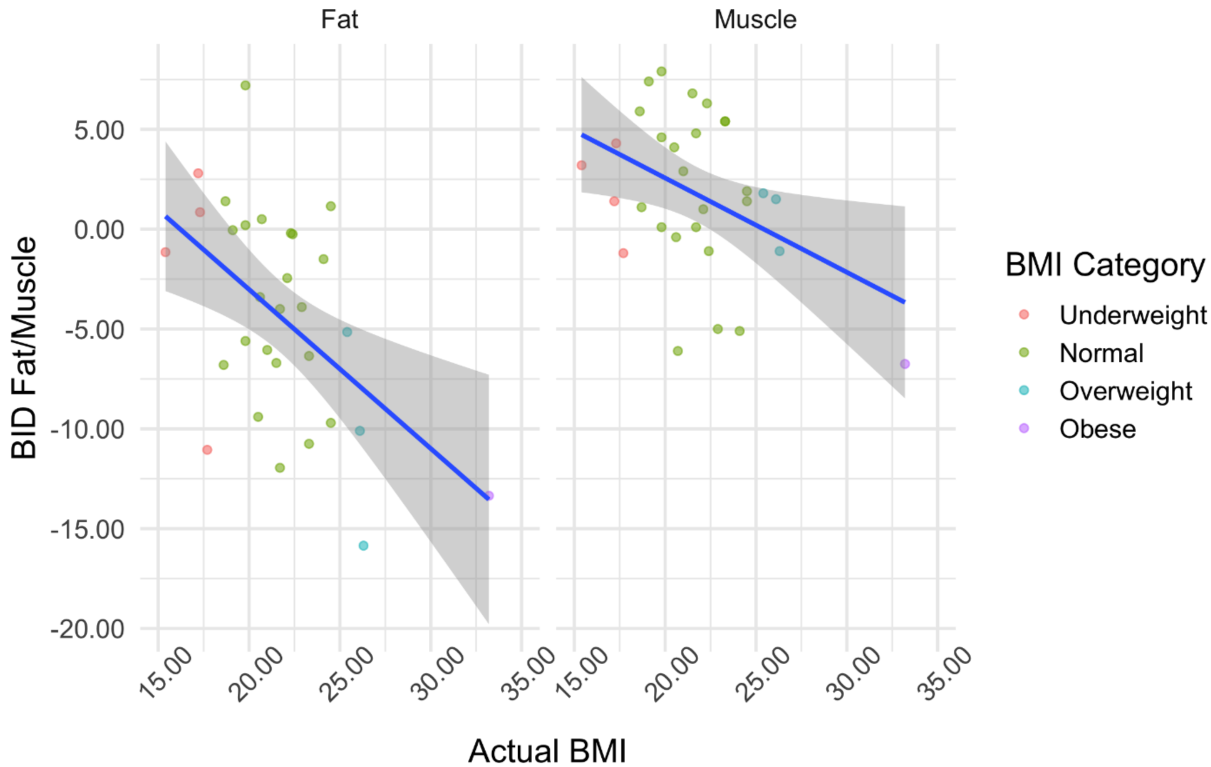
For ideal body composition, there were no significant correlations between ideal fat mass and actual BMI/fat mass/SMM, determined using Spearman's Rank correlations (all *p*s > .05). Similarly, there were no significant correlations between ideal muscle mass and actual BMI/fat mass/SMM, determined using Pearson's correlations (all *p*s > .05). This suggests that one's ideal body composition was not significantly associated with actual body composition.

There were significant negative correlations between BID fat (the discrepancy between actual and perceived fat mass) and actual BMI ($r = -.51$, $p = .004$) and fat mass ($r_s = -.60$, $p <$

.001). Similarly, BID muscle (the discrepancy between actual and perceived muscle) was significantly negatively correlated with actual BMI (*r* = -.41, *p* = .023) and actual SMM (*r* = -.50, *p* = .005). This indicates that both fat and muscle mass BID were associated with an increase in BMI, such that underestimation of fat and muscle mass were both associated with an increased overall body mass, as demonstrated in Figure 6.6. Similarly, muscle mass underestimation was associated with increased actual SMM and fat mass underestimation was associated with increased actual fat mass. These patterns of perceptual accuracy are consistent with the contraction bias explanation which has been demonstrated in BMI perception tasks, where increases in actual BMI are associated with underestimation and decreases in actual BMI are associated with overestimation (e.g. Cornelissen et al., 2015), except here it applies to the FATM/SMM dimensions.

Figure 6.6

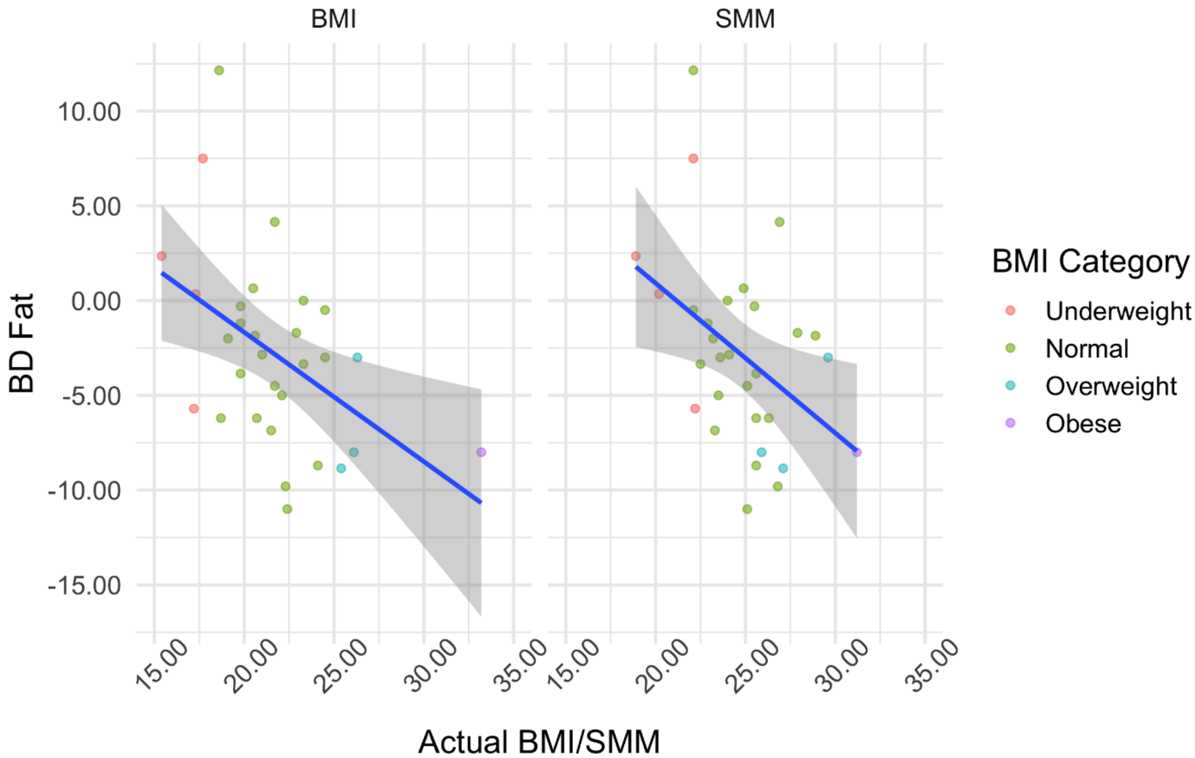
The relationship between actual BMI (x-axis) and the discrepancy between actual and perceived fat (BID Fat; left-grid) and muscle (BID Muscle; right-grid). The coloured points denote the BMI category of the participant.



There were significant negative correlations between the discrepancy between perceived and ideal fat mass (BD fat) and actual BMI (r = -.47, p = .009) and SMM (r = -.42, p = .021), indicating that desiring an ideal body that is lower in fat mass than perceived was associated with increases in actual BMI and SMM. This suggests that those with higher overall body mass and muscle mass tended to desire a body that was lower in body fat relative to their perceived. This is shown in Figure 6.7. The relationship between BD fat and actual fat was not significant (r_s = -.32, p = .089). There were no significant correlations between the discrepancy between perceived and ideal muscle mass (BD muscle) and actual body size/composition (all ps > .05).

Figure 6.7

The relationship between the discrepancy between perceived and ideal fat mass (BD fat) (y-axis) and the females actual BMI (left-grid) and skeletal muscle mass (right-grid). The coloured points denote the BMI category of the participant.



Men's Ideal (Female) Partner Body Composition. The descriptive statistics of the ideal female body composition created by men are presented in Table 6.6. First, the men's ideals were compared to the women's ideals, to determine whether there were similarities. Secondly, the men and women's ideals were compared to the women's actual body composition, to determine whether this ideal was similar or statistically different.

An independent samples Wilcoxon Signed-Ranks test indicated that there was no significant difference between the fat mass of the women's ideal and the men's ideal (female) partner ($W = 226.50$, $p > .05$). This suggests that ideal fat mass was similar for both men and women ($M_{Diff} = 2.47$). This indicates that generally, men and women's perceptions of ideal fat mass are similar. Men's ideal (female) fat mass was significantly lower than the actual fat mass of our sample of women ($W = 462.00$, $p = .005$; $M_{Diff} = 4.75$), which is not surprising since women also desired significantly lower fat mass for themselves ($W = 754.00$, $p < .001$; $M_{Diff} = 7.22$).

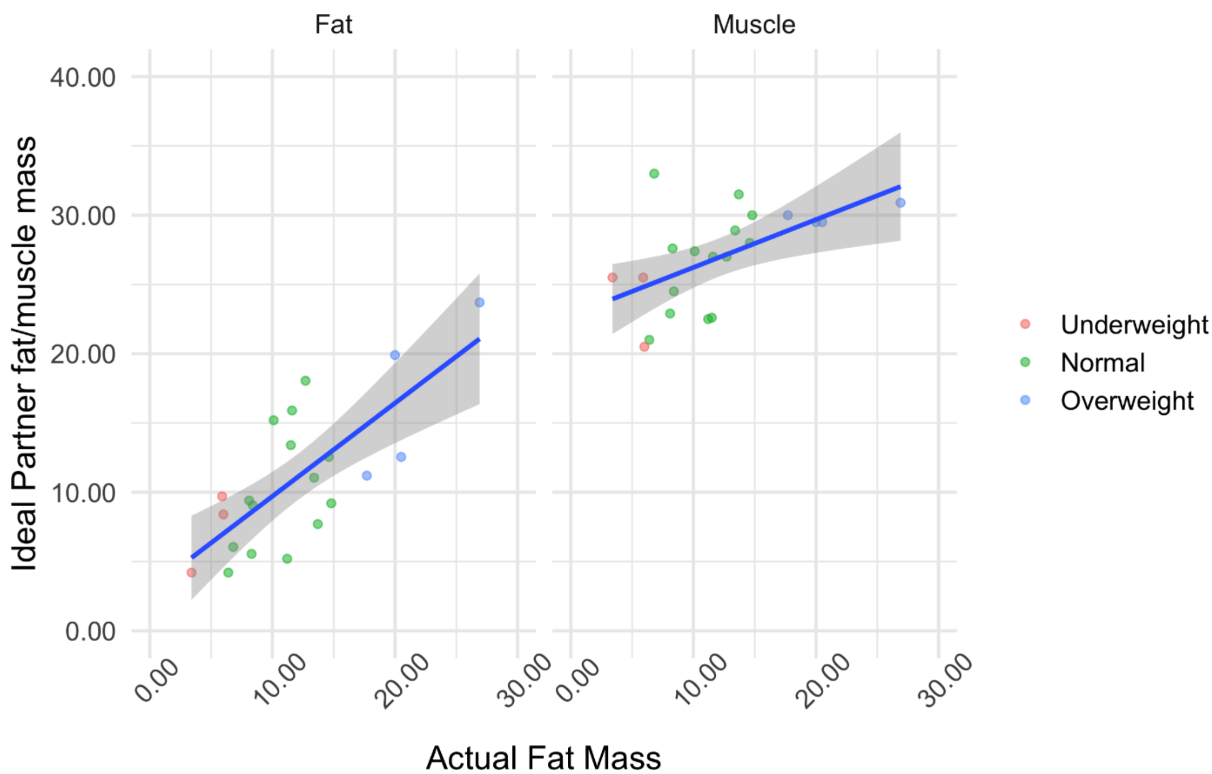
An independent samples t-test indicated that there was no significant difference between muscle mass of the women's ideal and the men's ideal (female) partner ($t(46.77) = 0.10$, $p > .05$). This suggests that ideal muscle mass was similar for both men and women ($M_{Diff} = -0.11$). The men's perception of their ideal (female) partner muscle mass, did significantly differ from the actual SMM of this current sample; it was significantly higher ($t(35.53) = -2.35$, $p = .025$; $M_{Diff} = 2.15$), which is not surprising since women also desired significantly higher muscle mass for themselves ($t(50.15) = -2.28$, $p = .027$; $M_{Diff} = 2.05$). This indicates that generally, men and women's perceptions of ideal muscle mass are similar.

There were significant negative correlations between men's ideal (female) partner fat mass and their DMS scores ($r = -.47$, $p = .042$) and SATAQ-4 Athletic Ideal Internalisation scores ($r = -.45$, $p = .030$). This suggests that men with a higher drive for muscularity/internalisation of an athletic body ideal desire a female body that is lower in body fat. Furthermore, there were significant positive correlations between men's ideal (female) partner fat mass and their actual BMI ($r = .49$, $p = .025$) and fat mass ($r = .74$, $p < .001$), indicating that as the men's actual body mass/fat increased, as did the fat mass of their ideal (female) partner. These findings demonstrate associations between the fat mass of the men's ideal female partner and their muscularity concerns and actual body fat/BMI. Figure 6.8 demonstrates the relationship between the men's fat mass/BMI and their ideal (female) partner fat mass.

For the men's ideal (female) muscle mass, there was a significant positive correlation with their actual fat mass (r_s = .64, p = .002). There were no significant relationships between their ideal (female) muscle mass and psychometric measures (all ps < .05). This indicates that men's ideal female muscularity is associated with their actual body fat, such that those with higher fat desired an ideal partner that was higher in muscle mass, but this was not related to their attitudinal body concerns or psychological wellbeing. Figure 6.8 demonstrates the relationship between the men's fat mass/BMI and their ideal (female) partner muscle mass.

Figure 6.8

The relationship between the men's actual fat mass (x-axis) and the fat (left-grid) and muscle (right-grid) of the men's ideal (female) partner. The coloured points denote the BMI category of the participant.



6.10.4 *Psychometric Properties of the Interactive Body Composition Scale*

Construct Validity.

Convergent Validity. Convergent validity was analysed by looking at the relationship between perceived (session 1) and actual body composition.

Perceived fat mass significantly positively correlated with actual fat mass (r_s = .44, p = .016, demonstrated in Figure 6.9) and actual BMI (r_s = .49, p = .006), but not actual SMM (r_s =

.24, $p > .05$). On average, perceived fat mass ($M = 11.43$, $SD = 5.27$) was significantly lower than actual fat mass ($M = 15.81$, $SD = 6.59$) (V = 63.50, $p < .001$). Perceived SMM did not significantly correlate with actual SMM ($r = .20$, $p > .05$; demonstrated in Figure 6.10), nor fat mass ($r_s = -.05$, $p > .05$) or BMI ($r = .05$, $p > .05$). On average perceived SMM ($M = 26.51$, $SD = 2.50$) was significantly higher than actual SMM ($M = 24.76$, $SD = 2.71$) ($t(29) = 2.42$, $p = .022$). These results indicate good convergent validity for the fat dimension, as perceived current estimations were positively correlated with both fat mass and BMI, indicating that as participant's body fat/mass increased as did their perceived fat estimations. However, on average, estimates were lower than their actual fat mass indicative of underestimation. The muscle dimension did not demonstrate adequate convergent validity, as there was no significant association between perceived and actual SMM and there was evidence of a tendency to overestimate.

Figure 6.9

The relationship between actual and perceived fat mass.

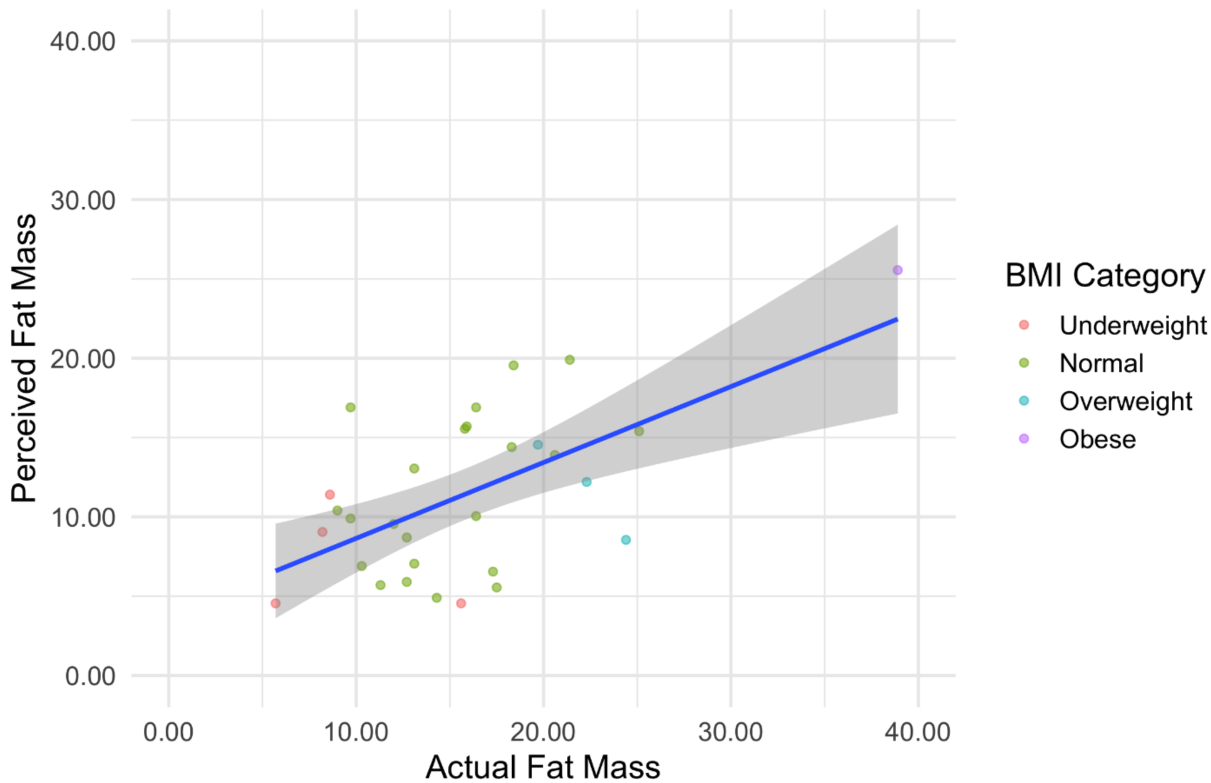
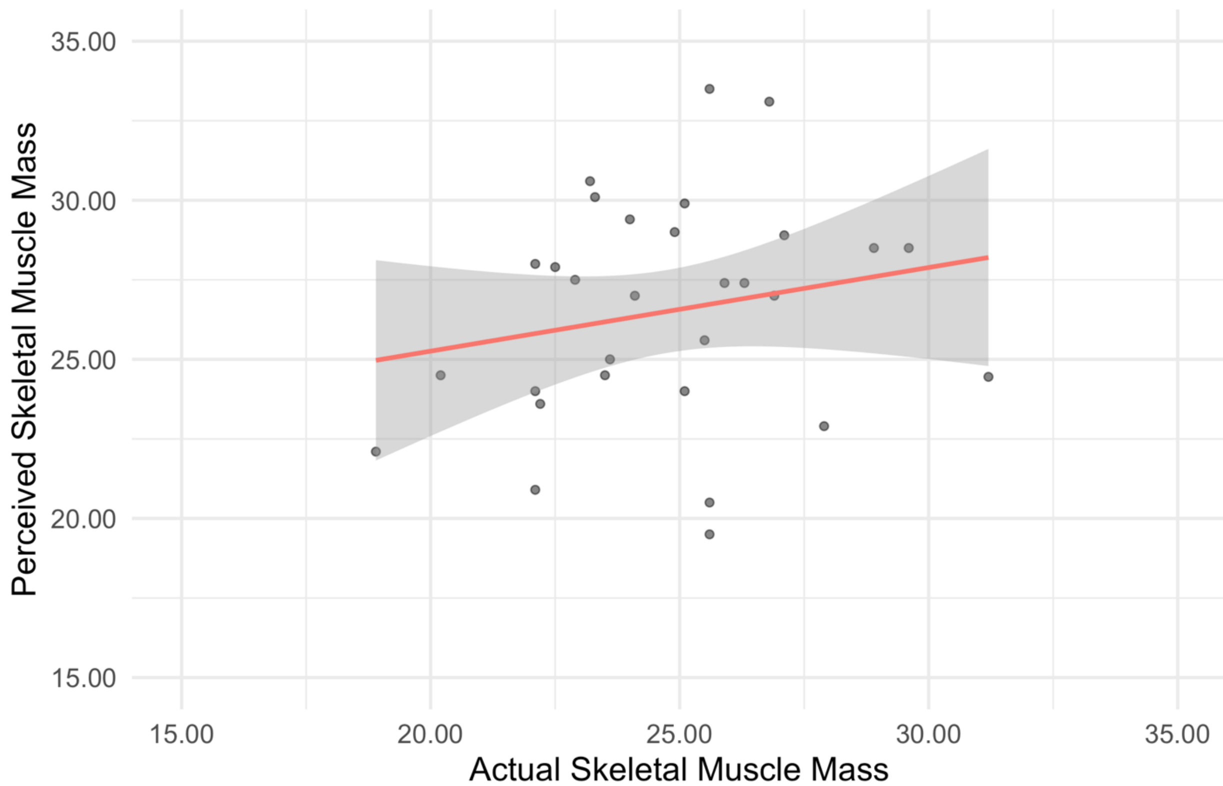


Figure 6.10

The relationship between perceived and actual skeletal muscle mass.

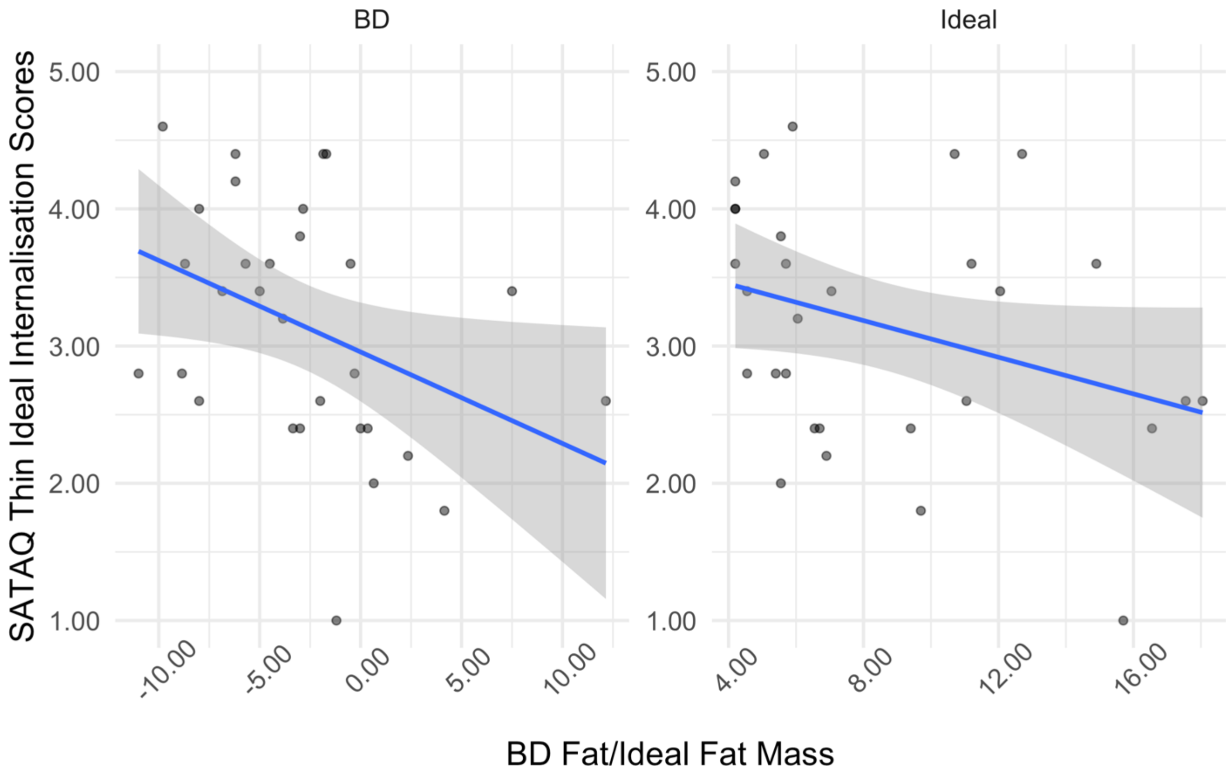


Concurrent Validity. Concurrent validity was analysed by looking at the relationship between perceptual BD (session 1) and attitudinal body image (scores from the psychometric measures related to body image: EDE-Q, BSQ, DMS, SATAQ-4 thin and athletic internalisation).

For the fat estimations, BD fat was significantly negatively correlated with SATAQ-4 thin ideal internalisation (r = -.38, p = .038), indicating that higher internalisation of a thin body ideal was significantly associated with desiring an ideal with less body fat (see Figure 6.11). This remained significant when controlling for actual fat mass (r = -.37, p = .047). Fat BD also significantly correlated with EDE-Q Restraint subscale (r_s = -.54, p = .002), indicating that increased dietary restraint was associated with desiring an ideal body with lower fat than perceived. The relationship remained significant when controlling for actual fat mass (r_s = -.49, p = .007). Ideal fat was significantly negatively correlated with SATAQ-4 thin ideal internalisation (r_s = -.36, p = .048), indicating that internalisation of a thin-ideal was significantly associated with desiring an ideal body with lower fat than perceived (see Figure 6.11). This remained significant when controlling for actual fat mass (r_s = -.42, p = .022). For the estimations of muscle mass, BD and ideal muscle were not significantly correlated with any of the attitudinal measures (all ps > .05).

Figure 6.11

The relationship between SATAQ-4 Thin Ideal Internalisation scores (y-axis) and the discrepancy between perceived and ideal fat mass (BD fat; left-grid) and ideal fat mass (right-grid).



Discriminant Validity. Discriminant validity was analysed by looking at the relationship between perceptual BD and BID (fat and muscle) in session 1 and general psychological wellbeing from the psychometric measures (BDI and RSES).

There were no significant correlations between the body estimations and BDI/RSES (all *p*s > .05). This indicates that perceptual dissatisfaction with perceived body composition and distortion related to one's own body composition were not related to depressive symptoms or self-esteem.

6.10.5 *Test-retest Reliability*

To examine test-retest reliability, correlations between body composition estimation variables in session 1 and session 2 were conducted. For the fat estimations, there were significant positive correlations between time one and time two: perceived (r_s = .74, p < .001), ideal (r_s = .73, p < .001), BID (r = .78, p < .001), BD (r = .73, p < .001), and ideal partner (r_s = .75, p < .001). For the muscle estimations, there were no significant correlations between estimations in time one and time two: perceived (r = -.15, p > .05), ideal (r = .32, p > .05), BID (r_s = .13, p > .05), BD (r = -.15, p > .05), and ideal partner (r = .06, p > .05).

On average, the estimations did not differ across sessions, determined using independent samples t-tests or Wilcoxon Signed-Rank tests (all *ps* > .05), indicating that there were no significant differences between the means in sessions 1 and 2. The means and standard deviations for each body estimation are presented separately for both sessions in Table 6.7.

Table 6.7

Descriptive statistics of the body estimations in session 1 and session 2.

	Session 1		Session 2	
	Fat	Muscle	Fat	Muscle
Body Estimation	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
Perceived (n = 30)	11.43 (5.27)	26.51 (3.50)	12.81 (6.31)	26.70 (4.10)
Ideal (n = 30)	8.58 (4.42)	26.81 (4.12)	9.16 (4.46)	28.74 (4.15)
BID (n = 30)	-4.39 (5.44)	1.75 (3.96)	-3.00 (6.16)	1.95 (5.18)
BD (n = 30)	-2.84 (5.08)	0.30 (5.14)	-3.65 (5.32)	2.03 (5.85)
Partner ideal (n = 21)	11.05 (5.25)	26.92 (3.55)	11.44 (7.46)	28.20 (3.08)

Two-way random, consistency, average-measures intraclass correlations were used to assess the degree of consistency between estimations in sessions 1 and 2. The results are presented in Table 6.8. The Intraclass Correlation Coefficients (ICCs) were high and statistically significant for estimations of fat mass, exceeding the 0.70 and 0.80 criteria put forward by Nunnally (1978) and Carmines (1990). This indicates good absolute consistency for estimations of fat mass. For the muscle estimations, only the ICC for ideal muscle was statistically significant but did not meet the criteria. For perceived and ideal (female) partner muscle, the ICC value was low and not statistically significant, which indicates that there was not good absolute consistency between sessions.

Table 6.8

Intraclass Correlation Coefficients, 95% confidence intervals, and statistical differences between sessions 1 and 2, for each body estimation and dimension.

Body Estimation	ICC	95% CIs
	Fat	
Perceived (n = 30)	0.87***	0.73 – 0.94
Ideal (n = 30)	0.82***	0.62 – 0.91
Ideal partner (n = 21)	0.80***	0.50 - 0.92
	Muscle	
Perceived (n = 30)	-0.36	-1.86 – 0.35
Ideal (n = 30)	0.48*	-0.09 - 0.75
Ideal partner (n = 21)	0.12	-1.18 – 0.64

*** $p < .001$, ** $p < .005$, * $p < .05$

6.11 Discussion

Overall, a novel statistical model has been developed which allows for the prediction of 3D shape calibrated for body composition (in this case, fat and skeletal muscle mass), based on data from a sample of 221 Caucasian adults aged 18 - 45. This model was used to develop a new bi-dimensional interactive body composition scale for perceptions of female body shape, to overcome some of the limitations with existing scales (e.g. line-drawings based on artistic impressions, lack of statistical calibration, and a focus on male stimuli and validation). The scale was used to investigate women's self-estimates of their perceived and ideal body composition and men's ideal female partner body composition. The psychometric properties were evaluated and the findings indicate that this scale may be a useful tool for investigating perceptions of female body composition, however, development of the model and further validation work is necessary if the scale is to be used in future research or healthcare settings.

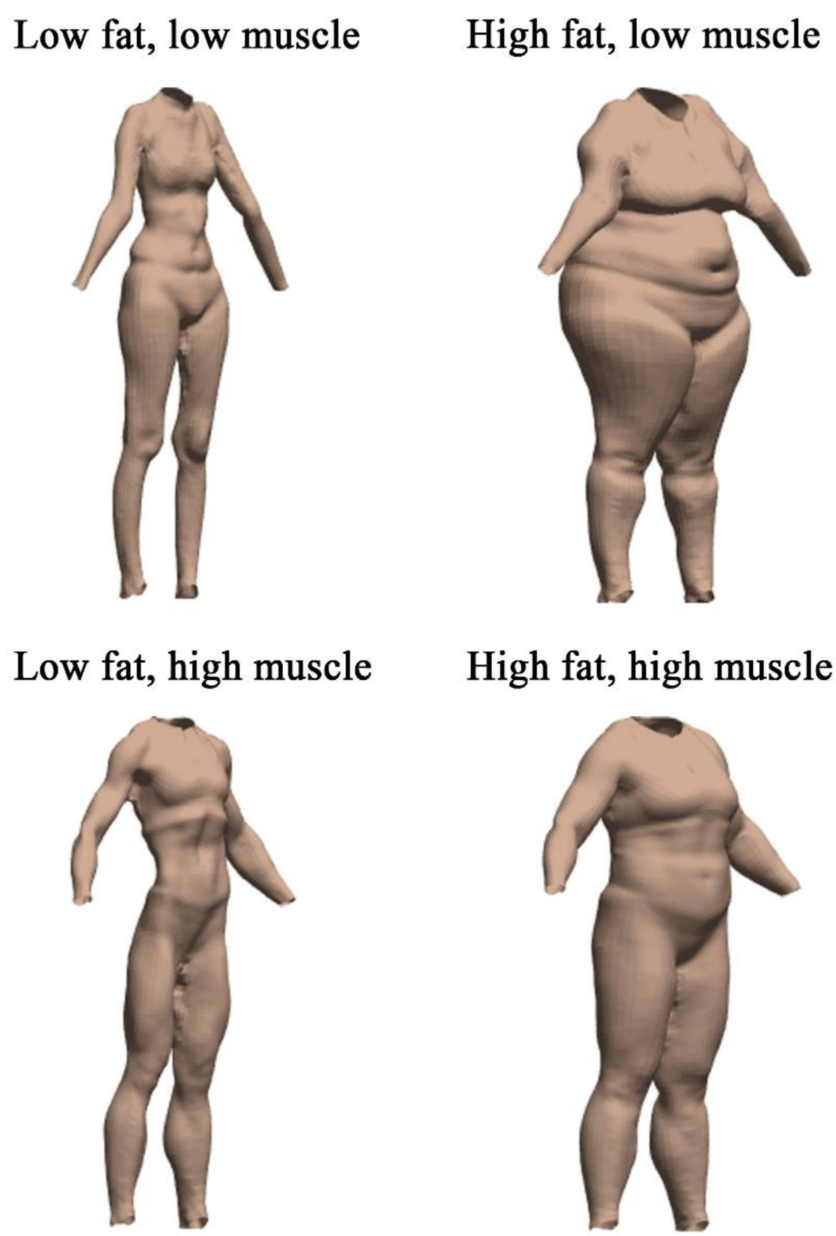
The psychometric properties of the fat dimension were good. Participants were able to perceive increases in fat mass, reflected by the positive relationship between the FATM of the stimulus and the fat ratings. Based on mean responses, the images of the lowest FATM were rated as very low and the images of the highest FATM were rated as high/very high. Construct validity was good, such that the women's perceived FATM significantly correlated with their actual fat mass and BMI. This indicates that women were generally able to associate their own increased fat/BMI with increased fat of the 3D shapes. There was a tendency towards underestimation, but similar to previous research using BMI this was consistent with predictions from contraction bias (e.g., Cornelissen et al., 2015; Cornelissen et al., 2013, also demonstrated in Studies 2 and 4 of this thesis), in that underestimation increased in magnitude as actual fat/BMI increased, whereas those with lower fat/BMIs were more accurate or overestimated slightly. Body dissatisfaction on the FATM dimension negatively correlated with thin ideal internalisation (as did ideal FATM) and dietary restraint, indicating that desiring an ideal with a lower body fat was associated with internalisation of a thin body and diet restriction. However, there was no relationship between fat dissatisfaction and any of the other psychometric responses, including depressive symptoms or self-esteem, suggesting that fat dissatisfaction from this scale does not capture concerns that may be indicated in other self-report measures or broader psychological concerns. Estimates on the FATM dimension were consistent and did not significantly differ between session 1 and 2 (two-three days later), indicating that this dimension provides a reliable visual measure of fat mass.

The psychometric properties of the SMM dimension were less satisfactory. The ratings indicated that the relationship between ratings of the amount of muscle and the SMM of the stimulus was significant but weak. This may be attributed, at least in part, to the fairly limited range and visibility of muscle mass in females. If the visibility of the muscle manipulation is unclear, participant's responses are unlikely to be consistent and may be less accurate. This may be reflected in the test-retest reliability findings, where the muscle estimations were not consistent between session 1 and 2. Similarly, perceived SMM was not related to actual SMM and SMM ideal/BD did not correlate with psychometric measures of body image or psychological wellbeing, indicating that this dimension does not demonstrate sound construct or discriminant validity. The results did show some evidence of contraction bias for perceived SMM, similarly to perceived FATM, which means that underestimation of muscle increased in magnitude as actual muscle mass/overall body mass increased. This is a unique finding as most work in females has used BMI stimuli (e.g., Cornelissen et al., 2015; Cornelissen et al., 2013). Groves et al. (2019) did find evidence of contraction bias in men using stimuli calibrated for BMI (based on waist and hip circumference) with varying levels of muscle mass and tone, but due to the lack of calibration between stimuli and participant's body composition until now, no specific evidence of contraction bias effects for muscle mass estimations has been reported.

Together, the findings provide some indication that the SMM dimension may need to be expanded to improve the visibility and to ensure it captures a range from very low to very high. In Study 7, participants used the full range of SMM when creating their body estimations, implying that perhaps the range was not wide enough. One way to address this would be to increase the diversity of scans at the extremes of fat and muscle mass, to capture greater variation in body shape and to increase the scope of the existing database of shapes/body measurements. Although, women naturally tend to have less SMM than men (Wang et al., 2001), making it difficult to capture women with very high amounts of visible muscle mass. Another option would be to extrapolate the statistical model to predict 3D body shape beyond the values of SMM captured and modelled here. This is possible with the existing database and the only limitation is the plausibility/reliability of the predicted shapes at the extreme ends (i.e. very low/very high SMM), as they will not be based on actual data from real women. For example, an extended range from 0 - 55kg of fat and 0 - 75kg of skeletal muscle may be predicted, see Figure 6.12. The ranges of SMM could be based on natural ranges that exist within the population, like the Somatomorphic Matrix which used the highest level of muscularity that could be achieved naturally without using steroids (Gruber et al., 1999). Although, it must be noted that limiting the range could create ceiling effects and limit responses from those who might want a body composition that is exaggerated beyond the normal range. If we are to capture perceptions of ideal/attractive/healthy female body composition, it may be necessary to capture extremes, even if they are not achievable or natural. Given that these tools may be used in a variety of samples, including clinical patients and athletes, subsequent work is warranted to determine the range of muscle that is most appropriate.

Figure 6.12

Visualisations of predicted shapes at combinations of low fat (0kg), low muscle (0kg), high fat (55kg) and high muscle (75kg) by extrapolating the statistical model.



Whilst ratings of the model according to their amount of fat/muscle were inversely related, such that as the ratings of fat increased the ratings of muscle decreased (which may be explained by the proposition that muscle is less visible when fat is increased), this was not the case for self-estimates or estimates of ideal partner. This research indicates that body composition estimates were independent and not related, i.e. there was no systematic relationship between fat and muscle for the body estimation responses. This means that those with a higher ideal fat mass did not necessarily also desire higher muscle mass. This provides further evidence for the independence of these body composition elements, as Sturman et al. (2017) indicated that they are neurally encoded separately and other research implies that they independently influence perceptions of attractiveness and health (e.g. Brierley et al., 2016; Lei & Perrett, 2020). Arguably, this adds additional support for modelling fat and muscle separately, rather than conflating body mass using BMI. Moreover, using fat mass rather than BMI is beneficial as preferences specifically related to increased/decreased body fat, not overall body weight can be identified. For example, Brierley et al.'s (2016) findings indicated that the most attractive female body was lower in fat but not muscle compared to that considered most healthy body size/shape. It also allows the opportunity to develop understanding of concerns and ideals in women that are related to body fat rather than overall mass, for example, in this research women desired lower body fat but not muscle mass.

Further investigation of the psychometric properties using a larger and more varied sample should be conducted. In this research (Study 7), the majority of the women (73.33%) and men (66.67%) were of a normal weight according to World Health Organisation BMI categories, with only one woman classified as obese and no men. The sample was also of a limited age range

(18 - 26, *M* = 20.25) due to sampling from a predominately student cohort. Furthermore, due to time and public health restraints on lab testing, the sample size was smaller than intended. If the body composition scale is to be utilised in future research, a wider validation study with a larger sample size must be conducted to determine its applicability. An online validation study (like Arkenau et al., 2020; Talbot et al., 2018) may be utilised if the scale is to be used in online research, although it must be acknowledged that this would not allow direct comparison to the individuals own body composition but self-reported height/weight/BMI. Given that some of the findings in this research demonstrated that body composition estimates were related to one's own BMI, this should still provide valuable insight into perceptions of female body composition. It may also be used to investigate perceptions that are not self-estimates such as attractiveness, health, weight, and norms.

Future work ought to identify the appropriateness of stimuli generalisability and applicability for different ethnicities. Gardner et al. (1999) argued for completely removing appearance-related features in body scales (e.g. facial features, ethnicity, clothing). For this research, we applied a Caucasian skin-coloured texture to the predicted 3D body shapes in MATLAB, which were developed from the Caucasian adult database. This limits the applicability in non-Caucasian samples and cross-cultural research for two reasons; i) a possible lack of identification with the skin-colour, and ii) differences in body shape, weight distribution, and body composition that occur in different ethnic groups (Misra & Khurana, 2011; Shiwaku et al., 2004; Wells, Cole, Bruner et al., 2008). This is similarly argued by Kagawa et al. (2006), stating that using the same images across different or multi-ethnic populations may be inappropriate due to differences in subcutaneous fat patterns. This signifies that there is a necessity to develop ethnic-/racial-specific stimuli, which may be achieved by developing separate databases and statistical models for different groups and using appropriate skin textures/colours.

Relatedly, we did not feature any other appearance-related features, such as photorealistic skin texture or clothing for this validation work, in part due to time and resource restrictions. We also did not feature head/hands/feet due to the additional noise they included in the PCA and the focus being on body shape. It may be argued that not including these features reduces the ecological validity of the stimuli (Mutale et al., 2016). Whilst the 3D shapes are more life-like, detailed, and better quality than traditional line-drawing/silhouette images, these stimuli may be developed to improve the ecological validity (e.g. using a photorealistic texture such as the one used in Study 5). Furthermore, there is the capability to apply the statistical model to individual scans (Maalin et al., 2020) which means that a person's body shape can be predicted at specific fat/skeletal muscle mass values and used in the method of adjustment task. Some research identified that personalized avatars (created by morphing individual scans for BMI with their photorealistic skin texture - presented in 2D and 3D in virtual reality) warranted more accurate self-estimates of body size compared to morphed scans without a photorealistic skin texture (Hudson et al., 2020). Although, the morphed scans without photorealistic texture (presented in 2D) still produced more accurate responses compared to using a generic line-drawing body scale. Therefore, the utility and benefits of personalising stimuli should be investigated in terms of applying a photorealistic texture (standardised as in Study 5 or an individual's own texture) and/or manipulating the individuals own body shape.

Lastly, future work may wish to explore other variables which contribute to body shape variation. Here, we chose to model body composition along two dimensions (fat and skeletal muscle) to test specific research questions, however, other anthropometric/demographic variables may be modelled, such as age or BMI. Given the range of BMIs in the database, a body model may be created to manipulate BMI from underweight to obese to generate high-quality standardised 3D body stimuli. This could address some of the limitations associated with CGI stimuli used in previous studies e.g., a lack of realism at the extremes (Alexi et al., 2019) and may be considered an improvement on existing line-drawing BMI rating scales (Hudson et al., 2020). Moreover, variables may be kept constant to control for their effect e.g. age, where a weak positive correlation between age and fat mass was found in the sample of women collected for the 3D database (Section 2.4, Chapter 2), despite limiting the sample to 18 - 45-year-olds. Thus, future research may wish to vary body composition whilst controlling for age. This is because age has an influence on female body size and shape (Wells et al., 2008; Wells et al., 2007), whereby younger bodies tend to be lower in fat/overall body mass (Williamson, 1993) and have a more hourglass shape (Wells et al., 2008). A lower BMI and an hourglass body shape are both indicators associated with a more fertile body and higher reproductive value, which both sexes may be sensitive to (Tovée et al., 2002), and may therefore be considered more evolutionary advantageous and attractive. Moreover, the societal value placed on youthfulness for women, including but not limited to body size/shape, means that an ageing body may be considered detrimental to physical attractiveness (Halliwell & Dittmar, 2003). Therefore, a preference for a lower body fat may reflect a desire for a more youthful body shape as this is considered more attractive. This should be taken into consideration when interpreting the findings from this study, and when designing stimuli for future work by controlling for age (as in the Daz stimuli developed in Section 2.3, Chapter 2), to ensure that body composition manipulations do not also reflect body shape changes driven by ageing.

In conclusion, 3D scanning technology is an efficient tool for accurately capturing high-quality human body shapes, which combined with PCA allows the visualisation and modelling of body shape variation. In this chapter, a novel statistical analysis for modelling 3D body shape along two dimensions of body composition (fat and skeletal muscle mass), derived from body scans and composition measurements from 221 Caucasian adults aged 18 - 45 was presented. The plausibility, reliability, and validity of the model were investigated in non-clinical adult samples. This is the first model to statistically map female 3D body shape to body composition for use in perceptual body image research, although, future development and further psychometric testing is required. Nevertheless, there are many possibilities for the extension of this work, including stimuli development (i.e. individualisation, photorealistic skin texture, extrapolation of ranges etc.), modelling of other body measurements, ethnic-/race-specific models, and use as stimuli in a range of research settings (e.g. intervention work, attractiveness, health etc.).

Chapter 7: General Discussion

The overall focus of this thesis was to develop and assess the reliability, validity, and utility of measures/techniques used in perceptual body image research, and to investigate the factors associated with perceptions of female body size/shape. This area of research, including the development of tools and interventions for assessment of body image, has crucial clinical and health applications and outcomes. The research presented in Chapter 1 indicated that perceptions of female body size/shape are influenced by a variety of factors, including actual body size/shape, attitudinal body image and psychological concerns, and socio-cultural influences, so these factors were considered throughout the studies presented in this thesis. Across the studies, methodological concerns with existing techniques were addressed, novel analyses were introduced, and the efficacy of using 3D and computer-generated (CG) models were considered. Below, the main findings from this thesis are outlined, and the implications, limitations, and impact for future work are discussed.

7.1 Summary of Empirical Findings

7.1.1 *Chapter 3*

In Study 1, the longer-lasting effects of a novel body size perception intervention, which uses Cognitive Bias Modification (CBM) to manipulate categorical perceptions of ‘thin’ and ‘fat’ body sizes (using CG bodies varying in BMI), was investigated. As in previous research, a sample of women identified as having high body concerns (e.g. Gledhill et al., 2017; Irvine et al., 2020) was recruited. The relationships between categorical perceptions, self-specific perceptual body image (perceived current and ideal body size/shape), and psychological concerns were explored across 30 days. The results indicated that the CBM intervention condition (inflationary feedback) produced a shift in the thin/fat categorical boundary towards a higher BMI by approximately 5 BMI units, which means that the boundary at which participant's started considering the body size of the model as 'fat' moved from the low end of the normal BMI category to the border of the overweight BMI category, and was maintained for up to 30 days. The control group – receiving feedback which did not aim to shift their categorical boundary – showed a smaller increase in the thin/fat categorical boundary towards a higher BMI by approximately 2 BMI units, which lasted for up to 30 days. This suggests that the CBM protocol may have two levels of effectiveness: i) a perceptual or 'regression towards the mean' effect – based on repeated viewing of the full range of body sizes, and ii) a cognitive effect - based on the feedback which challenges how the bodies are being categorised. Both groups demonstrated a decrease in psychological concerns across the 30 days and there were no significant changes in perceived or ideal body size/shape between day 1 and 30. There were no significant relationships between categorical perceptions of 'thin' and 'fat' and self-specific perceptual body image or psychological concerns/attitudinal body image.

In Study 2, performance on these tasks at baseline were compared to a novel sample of women with low/mild body concerns, to allow further investigation of perceptions as a function of concerns. The results indicated that irrespective of body concerns, the participant's ideal body size/shape was similar to previous research showing that the most attractive body size/shape is between 18 - 20 BMI units with a Waist-to-Hip Ratio (WHR) around 0.70 (Henss, 1995; Hildebrandt & Walker, 2006; Singh, 1993; Tovée et al., 2002). Both groups indicated a desire for a more curvaceous or 'hourglass' body shape (larger bust/hips and a smaller waist), again consistent with studies of female attractiveness/ideals (Overstreet et al., 2010; Singh & Singh, 2006). Perceptual body image was most strongly associated with the individuals own body size/shape than psychological concerns. There was evidence for the perceptual phenomenon ‘contraction bias’, where those with higher BMIs tended to underestimate their body size and those with lower BMIs tended to overestimate (e.g. Cornelissen et al., 2015; Cornelissen et al., 2013). The thin/fat categorical boundary was around 21 BMI units, which is at the low end of the normal BMI category. It was, on average, higher than the women’s ideal body size but lower than their actual body size, suggesting that they would consider their ideal as ‘thin’ and themselves as ‘fat’. This was not related to their actual body size/shape or psychological concerns.

A novel approach to assessing and analysing perceptual body image was employed, involving a computer software allowing the size and shape of a 3D model to be manipulated, which were then exported as 3D objects and analysed using Principal Component Analysis (PCA). The results suggest that the method produces comparable findings to research using alternative methods and the analyses conducted using circumference measurements/estimated BMI. The PCA allowed a more holistic analysis of body size, shape and composition, capturing variance that was not encapsulated by measurements/BMI alone, implying that it could be a useful technique for future research analysing 3D body models which have been manipulated by participant’s to generate 3D body estimates.

7.1.2 *Chapter 4*

In Study 3, a psychophysical body size discrimination task using novel CG bodies varying in BMI (creation and calibration described in Section 2.3, Chapter 2) was employed to determine the Just Noticeable Difference (JND) across the BMI spectrum (15 - 43 BMI units). The findings demonstrated that body size discrimination, when judging bodies increasing linearly in BMI, follows a pattern predicted by a well-established perceptual phenomenon (Weber’s law). This phenomenon states that the smallest difference between a pair of stimuli that can be identified reliably is a constant proportion of the stimulus magnitude (Gescheider, 1997), such that larger differences between BMIs are required as BMI increases for the difference to be reliably detected. For example, the data from this study indicated that a body of 18.00 BMI units would require a 0.69 BMI unit change for a difference to be reliably detected, whereas a body of 35.00 BMI units would require around double the amount of change (1.32 BMI units). These findings are in line with previous work using CGI bodies also calibrated for BMI using the same technique (Cornelissen et al., 2016). These results have implications for Figural Rating Scales (FRS) with equal spacing, such as large perceived differences between adjacent bodies for lower BMIs and small or undetectable perceived differences for higher BMIs. Therefore, in Study 4, the psychometric properties of two novel FRS with spacing based on the JND were investigated, i) a small 9-item scale (FRS-9) using quadruple the JND to determine spacing, and ii) a large 15-item scale (FRS-15) using double the JND. A continuous (interactive) BMI scale using the same CGI bodies spaced 0.25 BMI units apart was also employed, to investigate whether responses were influenced by the number of options available.

There was satisfactory construct validity for each of the FRS. Estimates of perceived current body size were accurate compared to actual BMI. Again, there was evidence of contraction bias, where those with lower BMIs tended to overestimate and those with higher BMIs tended to underestimate. Perceptual BD and ideal BMI were significantly associated with disordered eating psychopathology/body concerns and actual BMI. Women typically desired an ideal body size smaller than their own, which also reflected findings from previous literature indicating the most attractive/ideal BMI is around 18 - 20 BMI units (Hildebrandt & Walker, 2006; Tovée et al., 2002). The FRS-9 demonstrated good perceptual discriminability between adjacent bodies, which was not the case for the FRS-15, but nevertheless, they still demonstrated satisfactory test-retest reliability and construct validity, and performance was similar to the interactive body scale. This suggests that discrete options do not necessarily impede estimates of perceived current or ideal body size, or that perceptual discrimination between adjacent bodies is necessary for judgements to be valid/reliable. Overall, these FRS provide a good measure of perceptual body image using BMI.

7.1.3 *Chapter 5*

Here, 3D scans of females with a photorealistic skin texture at different BMIs (from underweight to obese), were used to explore perceptions of BMI category and attitudes towards whether the individual should lose weight. The scans were selected from the database developed and described in Section 2.4, Chapter 2.

The findings provided compelling evidence for contraction bias when categorising female bodies by BMI (i.e. underweight bodies overestimated and obese bodies underestimated), consistent with findings using photographs (e.g. Gledhill et al., 2019; Oldham & Robinson, 2017). Normal weight bodies were categorised most accurately, followed by overweight and underweight bodies, whereas obese bodies were often underestimated approximately two-thirds of the time. Mis-categorisation was most often by one BMI category. These findings indicate that visual perception of BMI labels in UK adults do not necessarily match World Health Organisation definitions and that female body size is often miscategorised based on vision alone. On average, there was disagreement that underweight bodies should lose weight, but agreement increased as the BMI of the body increased, and there was general agreement that obese female bodies should lose weight. Both categorisations and weight loss attitudes were modulated by observer sex and attitudinal/psychological concerns determined by two latent factors, the first comprising body image concerns and negative affect related to the self, and the second, a combination of anti-fat attitudes and internalisation of an athletic ideal. The amount of visual information was varied by presenting the body at either two angles (front and profile) or eight angles (360 degrees at 45-degree intervals), however, this had very little effect on categorisations and weight loss attitudes, suggesting that there is no significant advantage of seeing the body from 360-degrees and that displaying front and profile viewpoints are enough for a judgement to be made.

7.1.4 *Chapter 6*

Lastly, moving beyond BMI, an interactive body composition scale was developed, allowing the variation of both fat and skeletal muscle mass. This was developed using a statistical mapping between 3D body shape and body composition data from 221 Caucasian females aged 18 - 45, using a combination of PCA and linear regressions (described in Section 6.2, Chapter 6). The psychometric properties of the statistical mapping and interactive scale were investigated and evaluated in two studies. The findings indicated that the psychometric properties of the fat dimension were satisfactory, demonstrating good test-retest reliability, construct validity, and plausibility. Conversely, the psychometric properties of the muscle dimension were less satisfactory.

Using this scale, body composition estimates were related to the individual's body size/shape; revealing similar patterns to existing research using BMI scales, for example, evidence of contraction bias, such that those with higher fat/muscle tended to underestimate whereas those with lower fat/muscle tended to overestimate. There was correspondence between men's ideal (female) partner body composition and women's ideal body composition, which tended to be lower in fat but not muscle compared to the women's actual body composition. There were some relationships with psychological concerns, indicating that desiring a female body shape with lower body fat was associated with higher internalisation of a thin body ideal and dietary restraint for women, and a higher drive for muscularity/internalisation of an athletic body ideal for men.

7.2 Implications

7.2.1 *Actual Body Size/Shape*

One key outcome of this research is that the actual size/shape of the body being judged must be considered when assessing body perceptions. There was evidence of contraction bias in women's perceived BMI (Studies 1, 2, and 4) and perceptions of other women's BMI category status (Study 5). This indicates that lower BMI bodies are often overestimated in size and higher BMI bodies are often underestimated in size. This was also the case for self-estimates of body composition (Study 7). There were also relationships between attitudinal body image and the BMI of the bodies being judged. For example, the high body concerns group from Study 1 were significantly higher in BMI than those with low/mild concerns. This supports research demonstrating that overweight/obese BMI is associated with increased psychological/body image concerns (Schwartz & Brownell, 2004; Weinberger et al., 2016) and that obesity shares some common factors with eating disorders (Haines & Neumark-Sztainer, 2006; Neumark-Sztainer et al., 2007; Wilksch et al., 2014), which are usually categorised by low body weight. This supports the proposition that body image concerns need to be considered across the weight spectrum. This supports the core role of actual body size/shape in body image and for the inclusion of BMI/body composition in models of perceptual body image.

The link between overestimation at low-normal BMI/body composition has implications for potential relapse for patients recovering from an eating disorder. Cornelissen et al. (2015) found that women with Anorexia Nervosa with low BMIs made accurate self-estimates and were very sensitive to changes in body size, however, as their BMI increased they started to overestimate and become less sensitive to changes in body size. This rise in overestimation as BMI increases means they perceive themselves as larger than they actually are and this may impede healthy weight gain and result in attempts to reduce weight (Cornelissen et al., 2015), particularly since a fear of weight gain is a commonly acknowledged feature of eating disorders (Levinson et al., 2017; Linardon et al., 2018).

The economic and societal costs of obesity were discussed in Chapter 1, as were the psychological effects of being categorised into and/or identifying as part of a stigmatised group (Puhl & Heuer, 2009; Wu & Berry, 2018). This research found evidence of Weber's law using stimuli varying in BMI, such that as BMI increases larger differences between two body sizes are necessary for the difference to be reliably detected. This has implications for the detection of weight change and weight loss management, as larger changes will be needed at higher BMIs. Combined with contraction bias effects, this means that obese body sizes are often underestimated and larger changes in weight change are necessary for it to be detected. Moreover, there is evidence of links between perceived overweight status (accurate or not) with negative psychological outcomes (Daly et al., 2017, 2020; Robinson et al., 2017) and weight gain despite greater use of weight loss/control strategies (Feng & Wilson, 2019; Robinson et al., 2015). This suggests that identifying as being overweight/obese (whether accurate or stemming from overestimation) may be associated with negative psychological consequences. Some researchers, such as Tovée et al. (2000) and Moody et al. (2017), argue that treatments for body image and eating disorders could target general overestimation of weight and evaluation of others, not just self-specific perceptions. This has implications for public health strategies towards obesity reduction, due to the adverse effects on individuals associated with weight stigma (Puhl & Heuer, 2010). In Study 5, the findings indicated that anti-fat attitudes and psychological concerns were associated with slight increases in the accuracy of BMI category judgements and stronger agreement that overweight/obese females should consider losing weight. Polivy et al. (2014) state that underestimation of overweight/obesity may be a protective mechanism. Further investigation of the links between stigma and perception of body size may be explored.

7.2.2 *Female Ideals*

Throughout this thesis, it was found that ideal body size/shape was consistent with previous findings that the ideal or most attractive female body is at the low end of the normal BMI category (approximately 18 - 20 BMI units) (Tovée et al., 2003; Tovée & Cornelissen, 2001; Tovée, et al., 2002; Wardle & Johnson, 2002). Ideal body size/shape was generally consistent irrespective of body concerns, although there was some modulation from actual body size and psychological concerns, purporting the strength and pervasiveness of female body ideals for women. Those with higher BMIs tended to have a larger discrepancy between their perceived and ideal body size/shape, which may be considered a perceptual marker of body dissatisfaction (Williamson et al., 1993) and may be associated with decreased psychological health (Muennig et al., 2008). Thin-ideal internalisation is a risk factor for dietary restraint and disordered eating symptomology (Striegel-Moore & Bulik, 2007; Thompson & Stice, 2001), with increased risk associated with having a higher BMI (Stice & Shaw, 2002), signifying the implications of valuing and striving for a thin body.

It was also found that women tended to overestimate underweight and underestimate obese female bodies relative to male observers, and were more likely to agree that low-normal weight women should lose weight (particularly when they had average to increased anti-fat attitudes/athletic ideal internalisation) (Study 5). This is not surprising given the prevalence and value of the female thin ideal in Western society and the expectations on women to achieve this ideal (Garner et al., 1980; Spitzer et al., 1999; Sypeck et al., 2004), suggesting that women's perception of other women's body size may be influenced by sociocultural body size norms and ideals (Robinson, 2017). An evolutionary perspective may provide some explanation for men's accuracy. One key physical cue of female attractiveness, health, fertility, and youth is body size (Singh, 2002; Smith et al., 2007; Tovée et al., 2002; Tovée et al., 2012), so accurate perception and sensitivity towards this cue is evolutionary advantageous as it promotes an efficient mate selection strategy that favours reproductive success, such that the ability to accurately recognise a woman's BMI based on vision alone is advantageous as it supports efficient selection. Similarly, attitudes towards weight loss may reflect an evolutionary preference for a healthy, attractive, and fertile female body.

Moving beyond BMI, it was found that women desired lower body fat relative to their perceived, but their desired muscle was not significantly different. This does not indicate that women are dissatisfied with their levels of muscularity, as may be hypothesised considering evidence of a rise in an athletic or 'fit' ideal for women (see e.g. Bozsik et al., 2018; Gruber, 2007). Although further validation of the muscle dimension of the interactive body composition scale is necessary, tentative findings indicate that women's desire for a thin ideal is the primary concern. Furthermore, the ideal female body composition was similar for men and women. Some research found that women overestimate men's preferences for thinness for long- and, more so, short- term relationships (Lei & Perrett, 2020), but this research supported previous findings indicating a correspondence between men and women's perceptions of ideal female body size/shape/composition (e.g. Benninghoven et al., 2007; Crossley et al., 2012; Fingeret et al., 2004). Again, from an evolutionary perspective, this correspondence promotes an efficient mate selection strategy i.e., is advantageous for women to accurately identify and match the physical cues the opposite sex prefers as it optimises mating potential and success (Buss, 1988, 1989), and body composition may reflect cues of physical health, attractiveness, fertility, and youth that both sexes are sensitive too.

7.2.3 *3D Stimuli*

This research has methodological implications for the use of 3D body scanning in future body size perception research. In a BMI categorization task (Study 5), 3D scans of females with a standardised photorealistic skin texture were used. The results were expected based on previous findings and comparable to research using photographs (Gledhill et al., 2019; Oldham & Robinson, 2017), suggesting that 3D scans may be a viable alternative to photographs in future body size/shape perception research. They may even be advantageous due to the ability to apply a standardized skin texture, reducing the potential impact of extraneous appearance-related features which can often be present in photographs. They can also be presented in 2D from any angle (i.e. in laboratory and online research) and 3D (life-sized/moveable) in VR environments, which enables these stimuli to be used in a variety of research settings.

In addition, predicted 3D body shapes, based on statistical mappings with anthropometric data, using a combination of PCA and linear regressions, can be used as stimuli. In Chapter 6, we used predicted 3D body shapes statistically calibrated to vary in fat and skeletal muscle mass, based on anthropometric data and scans taken from 221 Caucasian adults aged 18 - 45. This technique can be applied to model other anthropometric variables such as BMI and/or age, to create stimuli varying along the given dimension/s. This allows for 3D stimuli to be created that are correctly calibrated based on statistical mappings, as opposed to relying on artistic impressions or replications of existing figures. The findings from Study 7, demonstrated findings consistent with previous research, such as women's desire for lower body fat, consistency between men and women's ideal female body composition, and contraction bias in self-estimates. This suggests that the statistically calibrated stimuli are responded to as expected. This data-driven approach opens opportunities for the development of novel 3D body stimuli for body image research.

7.3 Limitations

A limitation of Studies 4 and 7, which were evaluating the psychometric properties of the perceptually-spaced FRS and interactive body composition scale, are the sample sizes. The current sample sizes were insufficient for robust statistical analysis due to time and public health (COVID-19) restrictions on lab testing, which meant that recruitment/data collection was terminated early. Therefore, these findings may be used as preliminary/pilot findings and a wider validation study with a larger sample size should be conducted to fully validate these results. Based on correlational results from Study 4, a power analysis (with a correlation value of .30, alpha of .05 and power of .80) revealed that approximately 67 participants are necessary. For Study 7, it was estimated that a sample size of between 43 and 364 women and 29 and 1716 men (based on correlation values between .06 and .40, alpha of .05 and power of .80) is necessary.

Due to ongoing restrictions, it may be necessary to conduct subsequent validation studies online. Some researchers have validated body scales using online studies (see e.g. Arkenau et al., 2020; Talbot et al., 2018) and have recruited a large number of participants. This approach limits a direct mapping between body estimations and the individual's actual body size/shape/composition, as self-reported height and weight (to calculate BMI) will be used instead of taking actual anthropometric measurements. Whilst self-reported BMI may result in some measurement error and bias, due to under-reporting of weight and over-reporting of height (Gosse, 2014; Robinson & Oldham, 2016; Visscher et al., 2006), on average, the magnitude of error is small (Engstrom et al., 2003) and it is a suitable alternative when taking measurements are not possible (Bulik et al., 2001). Although, if these stimuli are to be used in future research, validation in an online setting may be useful and warranted. The stimuli may also be used to investigate perceptions that are not self-estimates such as attractiveness, health, dominance, masculinity, and body norms, which do not necessarily require a direct mapping to the individuals own body measurements.

Another limitation is that the stimuli formed in this thesis are limited in applicability across different/multi-ethnic groups as they are based on Caucasian anthropometric data and appearance (i.e. the skin colour/texture). Some researchers have argued that stimuli without any appearance-related features (e.g. facial features, ethnicity, clothing) are beneficial to reduce identification with a certain ethnicity (Gardner et al., 1999). Whilst removal of appearance features may be useful for visual identification, it may be argued that not including these features reduces the ecological validity of the stimuli (Mutale et al., 2016) and it does not address a possible lack of identification with the body shape or weight distribution of the models. Research indicates that there are key differences in body shape, weight distribution, and body composition that occur in different ethnic groups (Misra & Khurana, 2011; Shiwaku et al., 2004; Wells et al., 2012), and as such, using the same images across different or multi-ethnic populations may be inappropriate. For example, Kagawa et al. (2006) found that Japanese males responses using a body composition scale displayed more variability and less consistency than Caucasian males responses, possibly due to differences in subcutaneous fat patterns which reduced identification with the images.

Likewise, the majority of this research focused on younger adults which reduces the applicability of both the findings and stimuli to older adults or adolescents. Research using individualised manipulation of photographs indicated that middle-aged adults (aged 47 - 65) experience body image concerns differently to younger adults (aged 18 - 37) (Bellard et al., 2020), where younger adults were more accurate at estimating their body size but experienced larger discrepancies between perceived and ideal body size, especially as attitudinal body dissatisfaction increased. The age range in this thesis was deliberately limited because body composition/weight distribution changes with increasing age (Wells et al., 2008; Wells et al., 2007), however, this means that older adults or adolescents may not identify with the stimuli which are based on body shapes of younger adults. Some researchers have proposed that population-specific scales/stimuli ought to be employed, for example, Byrne and Hills (1996) found that using adult FRS with adolescents may produce inaccurate results. However, the techniques used in this thesis can be adapted to suit different age groups. The statistical body model used in Chapter 6 can be adapted by compiling similar body scan and anthropometric data for older adults/adolescents/children etc., to suit the population being tested. Jones et al. (2018) used 3D scanning technology to develop scales for children varying in BMI, but due to issues with scan quality and realism, CG models replicating the scanned bodies were produced.

Similarly, the CG models used in Chapter 4 (described in Section 2.3, Chapter 2), may be developed based on population data which reflect the average shape of the particular age group in question.

7.4 Future Work

This work has introduced opportunities for potential areas of future research. Firstly, further examination of the beneficial components of presenting stimuli/interventions in Virtual Reality (VR) is warranted, particularly when directly compared to the 2D alternative. Irvine et al. (2020) found that presenting the body size perception CBM intervention (Study 1) in immersive VR was beneficial. However, the stimuli were not exactly matched to the 2D version and a modified paradigm was used, where body stimuli were presented until a response was given instead of a brief masked presentation of each body, which may partly be responsible for the improvement in effectiveness. Future trials ought to employ the intervention in 2D and 3D VR with the same stimuli and presentation times so that direct comparisons and conclusions regarding the applicability, clinical utility, and future development can be made. The effectiveness of VR methods compared to traditional approaches must be determined, as VR is becoming increasingly popular for body image disturbance assessment and intervention (Ferrer-García & Gutiérrez-Maldonado, 2012; Gregg & Tarrier, 2007; Marco et al., 2013).

In Study 5, the utility of presenting a 360-degree view of a female 3D body model (eight angles at 45-degree intervals) compared to two angles (front- and profile- view) was investigated. These results did not demonstrate any significant benefit of additional viewpoints on BMI categorization accuracy or any significant effect on attitudes towards weight loss, indicating that viewing front and profile viewpoints of a body is enough for an individual to make a judgement.

This supports literature indicating that three-quarter and profile viewpoints adequately capture a variety of anthropometric cues necessary for body size discrimination (Cornelissen et al., 2018) and a combination of frontal and profile viewpoints sufficiently capture anthropometric cues (Cohen et al., 2015; Rilling et al., 2009). Research by Hudson et al. (2020) did not find any significant benefit of presenting individualised avatars varying in BMI in an interactive VR environment (allowing viewing of front and 45-degree viewpoints) compared to 2D static versions of the same bodies (front-view only), on judgements of perceived current, ideal, and achievable body size. Holder and Keates (2006) found that presenting FRS life-sized resulted in more accurate self-estimates. Thus, it remains unclear which elements of VR are beneficial in body size perception research and what tasks it is particularly beneficial for. Further exploration of presenting body stimuli in immersive VR should be examined with a focus on evaluating what components of VR presentation are beneficial (e.g. life-sized model, 3D volumetric shape, immersive experience etc.). This could be investigated using the 3D models presented in Study 5 and exports of the 3D shapes from the PCA model of body composition (Chapter 6), as 3D objects can be presented in both 2D and 3D in VR.

Secondly, the novel approach to modelling body composition and the interactive body composition scale developed in Chapter 6 warrants further investigation, validation, and evaluation. It was previously mentioned that a larger sample size is necessary and that this may have to be conducted in an online setting. The sample size should be extended to capture a wider range of ages and body sizes, as the current sample was limited in those respects. Some recommendations for future stimulus development were made in Section 6.11, Chapter 6. The positive relationship between BMI/fat mass and age indicates that even when restricting the database of bodies to 18 - 45-year-olds, there may still be influences from age that have not been controlled for in the current research. Therefore, future work may wish to control for age when predicting 3D body shape from fat and skeletal muscle mass. Additionally, it was suggested that the current range of muscle mass in the PCA body model may need to be extended either by scanning/measuring additional people at the body composition extremes or by extrapolating outside of the current range and predicting 3D shapes that go beyond the current sample's anthropometric data. Future work ought to investigate the range of muscle mass that is sufficient and appropriate, and whether expansion of the range improves the plausibility, reliability, and validity. This technique may also be expanded to investigate the relationships between facial perceptions and body composition (see e.g. Coetzee et al., 2011; Lei et al., 2019), by separately analysing and modelling faces from the 3D scans.

Furthermore, as demonstrated in Maalin et al. (2020), the statistical modelling technique allows for an individual's 3D scan to be manipulated along the given dimensions/s entered into the model. See Figure 7.1 for an example of a female body scan manipulated to decrease in fat mass and Figure 7.2 for a male body manipulated to increase in skeletal muscle mass.

Figure 7.1

An individual scan of a female (left) with a fat mass of 26.60kg and skeletal muscle mass of 32.70kg. The manipulated scan on the right with a fat mass of 13.30kg and a skeletal muscle mass of 32.70kg. Taken from Maalin et al. (2020).

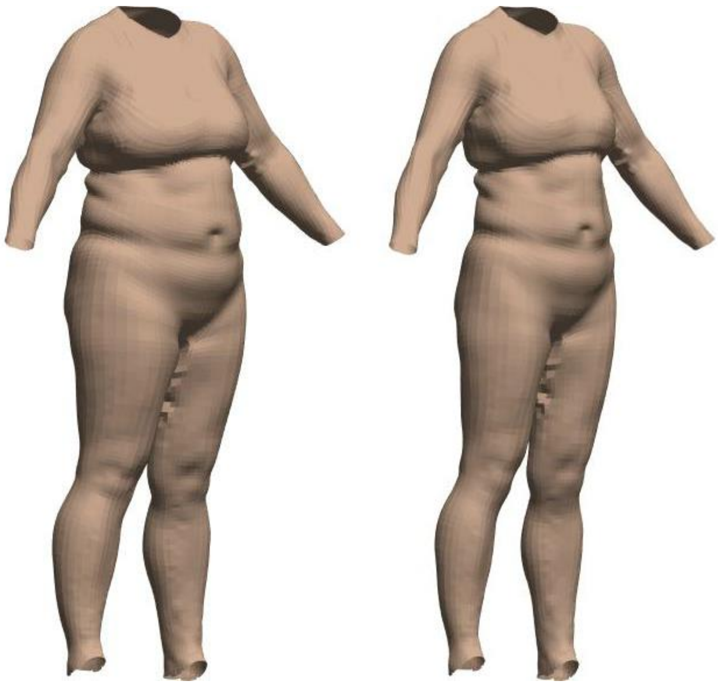
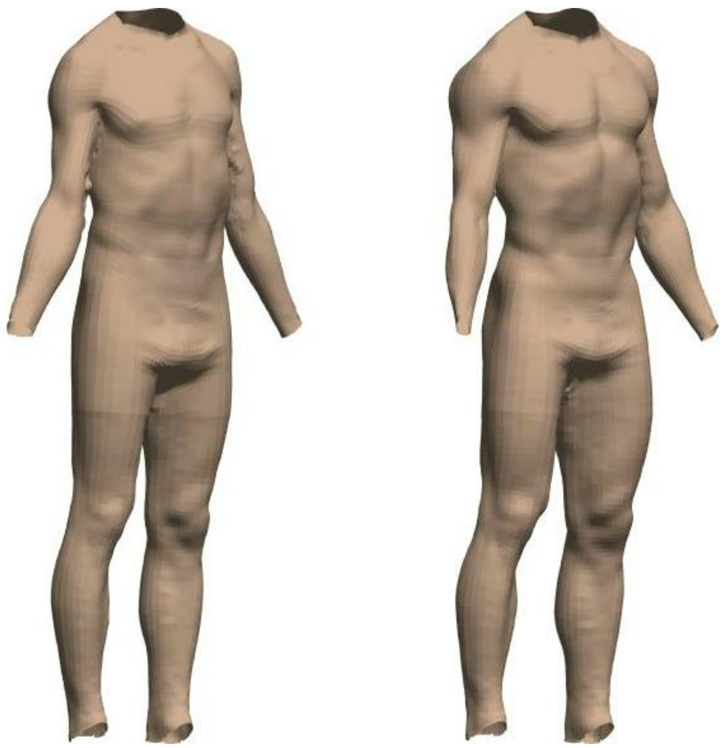


Figure 7.2

An individual scan of a male (left) with a fat mass of 7.00kg and skeletal muscle mass of 29.90kg. The manipulated scan on the right with a fat mass of 7.00kg and a skeletal muscle mass of 59.80kg. Taken from Maalin et al. (2020).



This allows for future work using individualised stimuli, where the 3D body shape of a specific individual can be manipulated. For example, Mölbert et al. (2018), Thaler et al. (2018), and Hudson et al. (2020) have utilised personalised 3D shapes manipulated to vary in BMI which were based on the individual's existing body shape and limb dimensions. This allows individual variation of underlying body shape and is more ecologically valid as it is closer to 'looking in the mirror' (Cornelissen et al., 2017). There are potential clinical/therapeutic implications as it allows individuals to visualise what their body would look like at a different body composition or BMI. In the context of healthy weight/body composition change, visualisation may be motivating for those wanting to achieve a certain body, in healthcare or fitness settings. Some research demonstrated that embodying a slimmer virtual body resulted in perceptions of one's own body as slimmer and increased body satisfaction (Preston & Ehrsson, 2014). Other research indicated that embodying a normal weight virtual body resulted in a reduction of body size/shape misperception in healthy controls and Anorexia Nervosa patients (Keizer et al., 2016). In the context of mirror exposure (to one's own body) therapy, preliminary evidence suggests there may be positive short-term psychological outcomes e.g. decreased body concerns and increased self-esteem and mood, which could be attributed to a habituation effect or reduced association between one's own body and negative emotions (Koskina et al., 2013; Vocks et al., 2007). Some researchers have argued then that exposure to one's body size and progressively increasing size in a VR environment could be promising as an additional therapeutic technique (Porras-Garcia et al., 2020). This research could be extended to employ individualised avatars. Contrarily, some research indicates that embodying a larger or 'fatter' avatar was associated with negative psychological outcomes (e.g. increased body anxiety and uneasiness) in college students (Ferrer-García et al., 2017) and Anorexia Nervosa patients (Provenzano et al., 2020 - using personalised avatars varied to represent -30% to +50% of the participant's real body weight). Further investigation of the psychological outcomes associated with viewing and/or embodying one's own body at different body sizes/compositions may be of future interest.

Lastly, whilst the statistical model produces appropriately calibrated 3D body models varying in body composition (or any given anthropometric measurements), the ecological validity and realism of the current models may be improved and developed in future work. For example, the hands, feet, and heads were removed from analysis in this thesis due to issues with postural and positional consistency which resulted in unnecessary noise in the PCA, and so the current stimuli are reduced in their realism and ecological validity (see e.g. Figures 7.1 and 7.2). We used a Caucasian skin colour on the predicted 3D body models but improvements could be made by adding hands/feet and a standardised photorealistic skin-texture (such as the one used in Study 5).

7.5 Conclusion

In this thesis, measures and techniques for perceptual body image research have been created, developed, and assessed. Novel 3D and CG stimuli which may be used in future research were developed, including novel body scales based on empirical data. Novel approaches to analysing 3D body shapes allowing a holistic understanding of perceptual body image and statistically calibrated predictions of 3D shapes along any given anthropometric dimension/s were introduced. Preliminary analyses suggest that these approaches may be useful in future research, though further investigation and development is warranted. The effectiveness of a novel body size perception intervention was investigated in a replication and extension study. Throughout, the relationships between attitudinal/psychological concerns, perceptions of body size/shape, and actual body size/shape were explored, revealing the stability and pervasiveness of female body ideals and the key role of actual body size/shape in perceptions.

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Appendices

Appendix A

Body Shape Questionnaire 16-B (BSQ 16-B; Evans & Dolan, 1993)

We should like to know how you have been feeling about your appearance over the **PAST FOUR WEEKS**. Please read each question and circle the appropriate number to the right. Please answer <u>all</u> the questions.

OVER THE PAST <u>FOUR WEEKS</u>:	Never	Rarely	Sometimes	Often	Very often	Always
1. Have you been so worried about your shape that you have been feeling you ought to diet?	1	2	3	4	5	6
2. Have you been afraid that you might become fat (or fatter)?	1	2	3	4	5	6
3. Has feeling full (e.g. after eating a large meal) made you feel fat?	1	2	3	4	5	6
4. Have you noticed the shape of other women and felt that your own shape compared unfavourably?	1	2	3	4	5	6
5. Has thinking about your shape interfered with your ability to concentrate (e.g. while watching television, reading, listening to conversations)?	1	2	3	4	5	6
6. Has being naked, such as when taking a bath, made you feel fat?	1	2	3	4	5	6
7. Have you imagined cutting off fleshy areas of your body?	1	2	3	4	5	6
8. Have you not gone out to social occasions (e.g. parties) because you have felt bad about your shape?	1	2	3	4	5	6
9. Have you felt excessively large and rounded?	1	2	3	4	5	6
10. Have you thought that you are in the shape you are because you lack self-control?	1	2	3	4	5	6
11. Have you worried about other people seeing rolls of fat around your waist or stomach?	1	2	3	4	5	6
12. When in company have your worried about taking up too much room (e.g. sitting on a sofa, or a bus seat)?	1	2	3	4	5	6
13. Has seeing your reflection (e.g. in a mirror or shop window) made you feel bad about your shape?	1	2	3	4	5	6
14. Have you pinched areas of your body to see how much fat there is?	1	2	3	4	5	6
15. Have you avoided situations where people could see your body (e.g. communal changing rooms or swimming baths)?	1	2	3	4	5	6
16. Have you been particularly self-conscious about your shape when in the company of other people?	1	2	3	4	5	6

Eating Disorder Examination Questionnaire 6.0 (EDE-Q; Fairburn & Beglin, 1994, 2008)

Eating Disorder examination questionnaire (EDE-Q 6.0)

Instructions: The following questions are concerned with the past four weeks (28 days) only.

Please read each question carefully. Please answer all the questions. Thank you.

Questions 1 to 12: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days) only.

	ON HOW MANY OF THE PAST 28 DAYS ...	NO DAYS	1-5 DAYS	6-12 DAYS	13-15 DAYS	16-22 DAYS	23-27 DAYS	EVERY DAY
1	Have you been deliberately **trying** to limit the amount of food you eat to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
2	Have you gone for long periods of time (8 waking hours or more) without eating anything at all in order to influence your shape or weight?	0	1	2	3	4	5	6
3	Have you **tried** to exclude from your diet any foods that you like in order to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
4	Have you **tried** to follow definite rules regarding your eating (for example, a calorie limit) in order to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
5	Have you had a definite desire to have an **empty** stomach with the aim of influencing your shape or weight?	0	1	2	3	4	5	6
6	Have you had a definite desire to have a **totally flat** stomach?	0	1	2	3	4	5	6
7	Has thinking about **food, eating or calories** made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?	0	1	2	3	4	5	6
8	Has thinking about **shape or weight** made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?	0	1	2	3	4	5	6
9	Have you had a definite fear of losing control over eating?	0	1	2	3	4	5	6
10	Have you had a definite fear that you might gain weight?	0	1	2	3	4	5	6
11	Have you felt fat?	0	1	2	3	4	5	6
12	Have you had a strong desire to lose weight?	0	1	2	3	4	5	6

PAGE 1/3 PLEASE GO TO THE NEXT PAGE

Eating Disorder examination questionnaire (EDE-Q 6.0)

Questions 13-18: Please fill in the appropriate number in the boxes on the right. Remember that the questions only refer to th past four weeks (28 days).

Over the past four weeks (28 days)….

13	Over the past 28 days, how many **times** have you eaten what other people would regards as an **unusually large amount of food** (given the circumstances)?	
14	… On how many of these times did you have a sense of having lost control over your eating (at the time you were eating)?	
15	Over the past 28 days, on how many **DAYS** have such episodes of overeating occurred (i.e. you have eaten an unusually large amount of food **and** have had a sense of loss of control at the time)?	
16	Over the past 28 days, how many **times** have you made yourself sick (vomit) as a means of controlling your shape or weight?	
17	Over the past 28 days, how many **times** have you taken laxatives as a means of controlling your shape or weight?	
18	Over the past 28 days, how many **times** have you exercised in a "driven" or "compulsive" way as a means of controlling your weight, shape or amount of fat, or to burn off calories?	

Questions 19 to 21: Please circle the appropriate number. Please note that for these questions the term "binge eating" means eating what others would regard as an unusually large amount of food for the circumstances, accompanied by a sense of having lost control over eating.

		NO DAYS	1-5 DAYS	6-12 DAYS	13-15 DAYS	16-22 DAYS	23-27 DAYS	EVERY DAY
19	Over the past 28 days, on how many days have you eaten in secret (ie, furtively)? … Do not count episodes of binge eating.	0	1	2	3	4	5	6
		None of the times	A few of the times	Less than half	Half of the times	More than half	Most of the time	Every time
20	On what proportion of the times that you have eaten have you felt guilty (felt that you've done wrong) because of its effect on your shape or weight? … Do not count episodes of binge eating.	0	1	2	3	4	5	6
			Not at all	Slightly	Moderately		Markedly	
21	Over the past 28 days, how concerned have you been about other people seeing you eat? … Do not count episodes of binge eating.	0	1	2	3	4	5	6

PAGE 2/3 PLEASE GO TO THE NEXT PAGE

Eating Disorder examination questionnaire (EDE-Q 6.0)

Questions 22 to 28: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days).

	ON HOW MANY OVER THE PAST 28 DAYS ...	NOT AT ALL	SLIGHTLY		MODERATELY		MARKEDLY	
22	Has your **weight** influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
23	Has your **shape** influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
24	How much would it have upset you if you had been asked to weigh yourself once a week (no more, or less, often) for the next four weeks?	0	1	2	3	4	5	6
25	How dissatisfied have you been with your **weight**?	0	1	2	3	4	5	6
26	How dissatisfied have you been with your **shape**?	0	1	2	3	4	5	6
27	How uncomfortable have you felt seeing your body (for example, seeing your shape in the mirror, in a shop window reflection, while undressing or taking a bath or shower)?	0	1	2	3	4	5	6
28	How uncomfortable have you felt about **others** seeing your shape or figure (for example, in communal changing rooms, when swimming, or wearing tight clothes)?	0	1	2	3	4	5	6

What is your weight at present? (Please give your best estimate.): ....

What is your height? (Please give your best estimate.): ....

If female: Over the past three to four months have you missed any menstrual periods?: **YES** ○ **NO** ○

If so, how many?: ○

Have you been taking the "pill"?: **YES** ○ **NO** ○

PAGE 3/3 **THANK YOU**

Beck Depression Inventory (BDI; Beck et al., 1961)

Beck's Depression Inventory

This depression inventory can be self-scored. The scoring scale is at the end of the questionnaire.

1.
- 0 I do not feel sad.
- 1 I feel sad
- 2 I am sad all the time and I can't snap out of it.
- 3 I am so sad and unhappy that I can't stand it.

2.
- 0 I am not particularly discouraged about the future.
- 1 I feel discouraged about the future.
- 2 I feel I have nothing to look forward to.
- 3 I feel the future is hopeless and that things cannot improve.

3.
- 0 I do not feel like a failure.
- 1 I feel I have failed more than the average person.
- 2 As I look back on my life, all I can see is a lot of failures.
- 3 I feel I am a complete failure as a person.

4.
- 0 I get as much satisfaction out of things as I used to.
- 1 I don't enjoy things the way I used to.
- 2 I don't get real satisfaction out of anything anymore.
- 3 I am dissatisfied or bored with everything.

5.
- 0 I don't feel particularly guilty
- 1 I feel guilty a good part of the time.
- 2 I feel quite guilty most of the time.
- 3 I feel guilty all of the time.

6.
- 0 I don't feel I am being punished.
- 1 I feel I may be punished.
- 2 I expect to be punished.
- 3 I feel I am being punished.

7.
- 0 I don't feel disappointed in myself.
- 1 I am disappointed in myself.
- 2 I am disgusted with myself.
- 3 I hate myself.

8.
- 0 I don't feel I am any worse than anybody else.
- 1 I am critical of myself for my weaknesses or mistakes.
- 2 I blame myself all the time for my faults.
- 3 I blame myself for everything bad that happens.

9.
- 0 I don't have any thoughts of killing myself.
- 1 I have thoughts of killing myself, but I would not carry them out.
- 2 I would like to kill myself.
- 3 I would kill myself if I had the chance.

10.
- 0 I don't cry any more than usual.
- 1 I cry more now than I used to.
- 2 I cry all the time now.
- 3 I used to be able to cry, but now I can't cry even though I want to.

11.
0 I am no more irritated by things than I ever was.
1 I am slightly more irritated now than usual.
2 I am quite annoyed or irritated a good deal of the time.
3 I feel irritated all the time.

12.
0 I have not lost interest in other people.
1 I am less interested in other people than I used to be.
2 I have lost most of my interest in other people.
3 I have lost all of my interest in other people.

13.
0 I make decisions about as well as I ever could.
1 I put off making decisions more than I used to.
2 I have greater difficulty in making decisions more than I used to.
3 I can't make decisions at all anymore.

14.
0 I don't feel that I look any worse than I used to.
1 I am worried that I am looking old or unattractive.
2 I feel there are permanent changes in my appearance that make me look unattractive
3 I believe that I look ugly.

15.
0 I can work about as well as before.
1 It takes an extra effort to get started at doing something.
2 I have to push myself very hard to do anything.
3 I can't do any work at all.

16.
0 I can sleep as well as usual.
1 I don't sleep as well as I used to.
2 I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
3 I wake up several hours earlier than I used to and cannot get back to sleep.

17.
0 I don't get more tired than usual.
1 I get tired more easily than I used to.
2 I get tired from doing almost anything.
3 I am too tired to do anything.

18.
0 My appetite is no worse than usual.
1 My appetite is not as good as it used to be.
2 My appetite is much worse now.
3 I have no appetite at all anymore.

19.
0 I haven't lost much weight, if any, lately.
1 I have lost more than five pounds.
2 I have lost more than ten pounds.
3 I have lost more than fifteen pounds.

20.
0 I am no more worried about my health than usual.
1 I am worried about physical problems like aches, pains, upset stomach, or constipation.
2 I am very worried about physical problems and it's hard to think of much else.
3 I am so worried about my physical problems that I cannot think of anything else.

21.
0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I have almost no interest in sex.
3 I have lost interest in sex completely.

Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965).

Please record the appropriate answer for each item, depending on whether you

Strongly agree, agree, disagree, or strongly disagree with it.

1 = Strongly agree

2 = Agree

3 = Disagree

4 = Strongly disagree

_____ 1. On the whole, I am satisfied with myself.

_____ 2. At times I think I am no good at all.

_____ 3. I feel that I have a number of good qualities.

_____ 4. I am able to do things as well as most other people.

_____ 5. I feel I do not have much to be proud of.

_____ 6. I certainly feel useless at times.

_____ 7. I feel that I'm a person of worth.

_____ 8. I wish I could have more respect for myself.

_____ 9. All in all, I am inclined to think that I am a failure.

_____ 10. I take a positive attitude toward myself.

Sociocultural Attitudes Towards Appearance Questionnaire 4 (SATAQ-4) – Thin/Low Body Fat and Muscular/Athletic Internalization Subscales (Thompson et al., 2011).

Directions: Please read each of the following items carefully and indicate the number that best reflects your agreement with the statement.

Definitely Disagree = 1 Mostly Disagree = 2 Neither Agree Nor Disagree = 3 Mostly Agree = 4 Definitely Agree = 5

1. It is important for me to look athletic. 1 2 3 4 5

2. I think a lot about looking muscular. 1 2 3 4 5

3. I want my body to look very thin. 1 2 3 4 5

4. I want my body to look like it has little fat. 1 2 3 4 5

5. I think a lot about looking thin. 1 2 3 4 5

6. I spend a lot of time doing things to look more athletic. 1 2 3 4 5

7. I think a lot about looking athletic. 1 2 3 4 5

8. I want my body to look very lean. 1 2 3 4 5

9. I think a lot about having very little body fat. 1 2 3 4 5

10. I spend a lot of time doing things to look more muscular. 1 2 3 4 5

Modified Weight Bias Internalization Scale (WBIS-M; Pearl & Puhl, 2014)

1. Because of my weight, I feel that I am just as competent as anyone.

2. I am less attractive than most other people because of my weight.

3. I feel anxious about my weight because of what people might think of me.

4. I wish I could drastically change my weight.

5. Whenever I think a lot about my weight, I feel depressed.

6. I hate myself for my weight.

7. My weight is a major way that I judge my value as a person.

8. I don't feel that I deserve to have a really fulfilling social life, because of my weight.

9. I am OK being the weight that I am.

10. Because of my weight, I don't feel like my true self.

11. Because of my weight, I don't understand how anyone attractive would want to date me.

Items are rated on a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree).

Anti-Fat Attitudes (AFA) Questionnaire (Crandall, 1994)

Antifat Attitudes Questionnaire (AFA)[1]

The AFA is scored using a Likert-type response format (0 = very strongly disagree; 9 = very strongly agree). Higher scores indicate stronger anti-fat attitudes.

Dislike

1. I really don't like fat people much.
2. I don't have many friends that are fat.
3. I tend to think that people who are overweight are a little untrustworthy.
4. Although some fat people are surely smart, in general, I think they tend not to be quite as bright as normal weight people.
5. I have a hard time taking fat people too seriously.
6. Fat people make me somewhat uncomfortable.
7. If I were an employer looking to hire, I might avoid hiring a fat person.

Fear of Fat

8. I feel disgusted with myself when I gain weight.
9. One of the worst things that could happen to me would be if I gained 25 pounds.
10. I worry about becoming fat.

Willpower

11. People who weigh too much could lose at least some part of their weight through a little exercise.
12. Some people are fat because they have no willpower.
13. Fat people tend to be fat pretty much through their own fault.

[1] Crandall, C.S. (1994). Prejudice against fat people: Ideology and self-interest. *Journal of Personality and Social Psychology*, 66, 882-894.

Drive for Muscularity Scale (DMS; McCreary & Sasse, 2000)

The Drive for Muscularity Scale

Please read each item carefully then, for each one, circle the number that best applies to you.

1	2	3	4	5	6
Always	Very Often	Often	Sometimes	Rarely	Never

1. I wish that I were more muscular.	1	2	3	4	5	6
2. I lift weights to build up muscle.	1	2	3	4	5	6
3. I use protein or energy supplements.	1	2	3	4	5	6
4. I drink weight gain or protein shakes.	1	2	3	4	5	6
5. I try to consume as many calories as I can in a day.	1	2	3	4	5	6
6. I feel guilty if I miss a weight training session.	1	2	3	4	5	6
7. I think I would feel more confident if I had more muscle mass.	1	2	3	4	5	6
8. Other people think I work out with weights too often.	1	2	3	4	5	6
9. I think that I would look better if I gained 10 pounds in bulk.	1	2	3	4	5	6
10. I think about taking anabolic steroids.	1	2	3	4	5	6
11. I think that I would feel stronger if I gained a little more muscle mass.	1	2	3	4	5	6
12. I think that my weight training schedule interferes with other aspects of my life.	1	2	3	4	5	6
13. I think that my arms are not muscular enough.	1	2	3	4	5	6
14. I think that my chest is not muscular enough.	1	2	3	4	5	6
15. I think that my legs are not muscular enough.	1	2	3	4	5	6

Source: McCreary, D.R., & Sasse, D.K. (2000). An exploration of the drive for muscularity in adolescent boys and girls. *Journal of American College Health, 48*, 297-304.

Note: If you use this scale, please forward any scientific papers resulting from your research to Dr. Don McCreary

Appendix B

Below, the BMI and World Health Organisation BMI category (detailed in Section 2.1.1, Chapter 2) for the full set of female computer-generated stimuli created and described in Section 2.3, Chapter 2 is presented (Table B.1).

Table B.1

The BMI and BMI category for each female computer-generated stimulus rendered for use as stimuli outlined in Section 2.3, Chapter 2.

BMI	BMI Category
14.25	
14.5	
14.75	
15	
15.25	
15.5	
15.75	
16	
16.25	Underweight
16.5	
16.75	
17	
17.25	
17.5	
17.75	
18	
18.25	

18.5	
18.75	
19	
19.25	
19.5	
19.75	
20	
20.25	
20.5	
20.75	
21	
21.25	
21.5	
21.75	
22	
22.25	
22.5	
22.75	
23	
23.25	Normal Weight
23.5	
23.75	
24	
24.25	
24.5	
24.75	
25	Overweight
25.25	

25.5	
25.75	
26	
26.25	
26.5	
26.75	
27	
27.25	
27.5	
27.75	
28	
28.25	
28.5	
28.75	
29	
29.25	
29.5	
29.75	
30	
30.25	
30.5	
30.75	
31	
31.25	
31.5	
31.75	
32	
32.25	Obesity Class I

32.5	
32.75	
33	
33.25	
33.5	
33.75	
34	
34.25	
34.5	
34.75	
35	
35.25	
35.5	
35.75	
36	
36.25	
36.5	
36.75	
37	
37.25	Obesity Class II
37.5	
37.75	
38	
38.25	
38.5	
38.75	
39	
39.25	
39.5	

39.75	
40	
40.25	
40.5	
40.75	
41	
41.25	
41.5	
41.75	
42	
42.25	
42.5	
42.75	Obesity Class III
43	
43.25	
43.5	
43.75	
44	

Appendix C

Reported below are additional information and analyses to supplement materials in Study 1, Chapter 3.

Daz Starter Bodies

Tables C.1 and C.2 contain information regarding the sliders and body measurements of the Daz starter bodies (underweight and obese) used in Study 1 and also in Study 2.

Table C.1

Information regarding the starting point of each slider for the two starter bodies used for the interactive 3D body estimates on Daz3D Studio.

Slider	Underweight	Obese
Body size	-34%	19%
Emaciated	84%	1%
Heavy	1.5%	69%
Pear figure	1%	1.5%
Voluptuous	1.5%	43%
Weight	1.5%	1.5%
Arm size	1%	1%
Breast implants	-15%	1.2%
Breasts natural	36%	8%
Chest width	-28.6%	8.2%
Chest young 1	3.8%	3.8%
Love handles	-9.2%	13%
Waist width	1.8%	1.8%
Abdomen Inout	10%	16%
Glutes size	1%	1%
Glute width lower	-.59%	24%

Slider	Underweight	Obese
Glute size 1	-6.5%	19%
Hip width 1	-76%	-76%
Thighs size	8.6%	-6.5%
Thigh thickness width	-.59%	-24%
Thigh thickness depth	.7%	.7%
Body tone	.83%	.83%
Bodybuilder	.01%	.01%
Upper arm size	1%	1%

Table C.2

Measurements taken from the starter bodies.

Measurement	Underweight	Obese
Height	185.10	185.10
Bust	80.32	126.95
Waist	56.04	114.46
Low Hip	84.33	139.92
Bicep	19.67	35.70
WHR	.66	.82
BMI assuming an age of 25	11.91	37.64

Participant Characteristics

Table C.3 presents the descriptive statistics of participant's actual body size/shape measurements. When looking at the sample distribution according to BMI category, 0 were underweight, 12 (31.58%) were normal weight, 11 (28.95%) were overweight, and 15 (39.47%) were obese on day 1, but one participant moved from the overweight to obese category at day 30. There were significant correlations between body size/shape variables at day 1 and 30 (n = 38):

BMI (r_s = .99, p < .001), WHR (r = .84, p < .001), WBR (r_s = .71, p < .001), BHR (r = .81, p < .001).

Table C.3

Descriptive statistics of participants' body size/shape, for both conditions and at both time points (days 1 and 30).

Variables	Intervention		Controls	
	Day 1	Day 30	Day 1	Day 30
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)
Height	165.29 (6.32)	-	165.13 (5.50)	-
BMI	28.12 (5.90)	28.01 (5.98)	28.41 (5.35)	28.41 (5.34)
WHR	0.84 (0.07)	0.82 (0.07)	0.80 (0.05)	0.79 (0.05)
WBR	0.92 (0.08)	0.90 (0.09)	0.88 (0.06)	0.88 (0.06)
BHR	0.92 (0.05)	0.92 (0.05)	0.91 (0.04)	0.90 (0.04)

Linear Mixed-Effects Models of the Thin/fat Categorical Boundary

A full summary of the Linear Mixed-Effects Model of Baseline Categorical Boundary results (Table C.4)

Table C.4

Summary table of the linear mixed-effects model of baseline categorical boundaries.

Fixed Effects	*b* Coefficient	*b* SE	CI	*t*	*p*
(Intercept)	21.24	0.59	20.11 – 22.37	36.10	< .001
Condition	-0.61	0.83	-2.25 – 1.03	-0.74	.467
Day [2]	1.69	0.44	0.85 – 2.53	3.88	< .001
Day [3]	2.18	0.44	1.35 – 3.02	5.01	< .001

Fixed Effects	*b* Coefficient	*b* SE	CI	*t*	*p*
Day [4]	2.44	0.44	1.60 – 3.27	5.59	< .001
Day [15]	2.25	0.44	1.41 – 3.09	5.16	< .001
Day [30]	1.70	0.44	0.87 – 2.54	3.91	< .001
Condition X Day [2]	0.53	0.62	-0.65 – 1.72	0.86	.389
Condition X Day [3]	1.43	0.62	0.24 – 2.61	2.31	.022
Condition X Day [4]	2.42	0.62	1.24 – 3.60	3.93	< .001
Condition X Day [15]	2.99	0.62	1.80 – 4.18	4.81	< .001
Condition X Day [30]	3.05	0.62	1.87 – 4.24	4.95	< .001
Random Effect	SD	Residual			
Participant ID (n = 38)	2.13	1.31			
Observations	227				
Log-Likelihood	-463.55				
AIC	902.11				
BIC	949.06				

A full summary of the of the linear mixed-effects model of perceptual training model is presented in Table C.5.

Table C.5

Summary table of the linear mixed-effects model of perceptual training.

Fixed Effects	*b* Coefficient	*b* SE	CI	*t*	*p*
(Intercept)	21.24	0.58	20.13 – 22.35	36.57	< .001
Condition	-0.61	0.82	-2.23 – 1.01	-0.75	.461
Training	0.18	0.42	-0.64 – 0.99	0.42	.678
Day [2]	1.69	0.42	0.88 – 2.50	3.99	< .001
Day [3]	2.18	0.42	1.37 – 3.00	5.16	< .001
Day [4]	2.44	0.42	1.62 – 3.25	5.75	< .001

Fixed Effects	*b* Coefficient	*b* SE	CI	*t*	*p*
Condition X Training	0.93	0.60	-0.22 – 2.08	1.56	.121
Condition X Day [2]	0.53	0.60	-0.62 – 1.68	0.89	.375
Condition X Day [3]	1.43	0.60	0.28 – 2.57	2.38	.018
Condition X Day [4]	2.42	0.60	1.27 – 3.57	4.04	< .001
Training X Day [2]	-0.48	0.60	-1.63 – 0.67	-0.80	.423
Training X Day [3]	-0.22	0.60	-1.36 – 0.93	-0.36	.718
Training X Day [4]	-0.35	0.60	-1.50 – 0.80	-0.59	.558
Condition X Training X Day [2]	0.45	0.85	-1.17 – 2.07	0.53	.595
Condition X Training X Day [3]	-0.11	0.85	-1.73 – 1.51	-0.13	.897
Condition X Training X Day [4]	-0.65	0.85	-2.28 – 0.97	-0.77	0.441
Random Effect	SD	Residual			
Participant ID (n = 38)	2.11	1.27			
Observations	304				
Log-Likelihood	-568.82				
AIC	1163.64				
BIC	1230.55				

Psychometric Measures

The descriptive statistics for each psychometric measure and correlations between measures can be found in Tables C.6 and C.7.

Table C.6

Descriptive statistics for each psychometric for each group on each day.

Variables	Day	Intervention	Controls	Overall	
		M (SD)	*M* (SD)	*M* (SD)	Range
BSQ	1	70.74 (12.08)	67.42 (13.42)	69.08 (12.71)	36.00 – 93.00
	4	67.89 (14.04)	63.11 (14.97)	65.50 (14.52)	33.00 – 96.00
	15	66.83 (15.39)	60.53 (16.98)	63.59 (16.32)	32.00 – 96.00
	30	66.00 (15.24)	60.05 (16.36)	63.03 (15.88)	32.00 – 95.00
RSES	1	15.11 (4.75)	15.21 (10.23)	15.16 (5.11)	4.00 – 30.00
	4	15.89 (4.31)	15.84 (5.34)	15.87 (4.78)	5.00 – 30.00
	15	16.22 (4.87)	15.63 (5.79)	15.92 (5.29)	4.00 – 30.00
	30	16.89 (5.37)	15.95 (5.60)	16.42 (5.44)	5.00 – 30.00
BDI	1	13.79 (7.28)	15.21 (10.23)	14.50 (8.79)	2.00 – 41.00
	4	11.58 (7.62)	11.47 (7.95)	11.53 (7.68)	1.00 – 32.00
	15	10.72 (7.49)	11.16 (8.16)	10.95 (7.74)	0.00 – 30.00
	30	12.00 (8.65)	11.58 (7.80)	11.79 (8.12)	0.00 – 30.00
EDE-Q Global	1	3.35 (0.93)	3.08 (0.99)	3.22 (0.95)	0.64 – 5.45
	4	2.68 (1.33)	2.49 (1.31)	2.59 (1.31)	0.42 – 5.72
	15	2.98 (1.32)	2.39 (1.26)	2.67 (1.31)	0.41 – 5.75
	30	3.10 (1.36)	2.74 (1.29)	2.92 (1.32)	0.29 – 5.60
EDE-Q Restraint	1	2.61 (1.21)	2.26 (1.20)	2.44 (1.20)	0.80 – 5.00
	4	1.84 (1.72)	2.08 (1.42)	1.96 (1.56)	0.00 – 6.00
	15	2.21 (1.71)	1.60 (1.45)	1.90 (1.59)	0.00 – 6.00
	30	2.38 (1.74)	2.08 (1.42)	2.23 (1.57)	0.00 – 6.00
EDE-Q Eating Concern	1	2.53 (1.37)	2.36 (1.43)	2.44 (1.38)	0.20 – 6.00
	4	1.74 (1.38)	1.79 (1.38)	1.76 (1.36)	0.00 – 6.00
	15	2.21 (1.57)	1.76 (1.40)	1.98 (1.48)	0.00 – 6.00
	30	2.31 (1.67)	2.05 (1.51)	2.23 (1.58)	0.00 – 5.80
EDE-Q Weight Concern	1	3.85 (1.03)	3.61 (0.95)	3.73 (0.98)	0.80 – 5.40
	4	3.37 (1.45)	2.87 (1.44)	3.12 (1.45)	0.40 – 6.00
	15	3.50 (1.50)	2.92 (1.47)	3.20 (1.49)	0.20 – 6.00

Variables	Day	Intervention	Controls	Overall	
		M (SD)	*M* (SD)	*M* (SD)	Range
	30	3.65 (1.51)	3.21 (1.46)	3.43 (1.48)	0.20 – 5.60
EDE-Q Shape Concern	1	4.41 (1.00)	4.11 (1.27)	4.26 (1.14)	0.75 – 6.00
	4	3.78 (1.43)	3.23 (1.72)	3.51 (1.58)	0.50 – 6.00
	15	3.99 (1.32)	3.27 (1.68)	3.62 (1.54)	0.62 – 6.00
	30	3.69 (1.36)	3.61 (1.65)	3.78 (1.50)	0.50 – 6.00
Thin-ideal internalisation	1	3.79 (0.77)	3.83 (0.74)	3.81 (0.75)	2.00 – 5.00
	4	3.85 (0.89)	3.84 (0.99)	3.85 (0.95)	1.40 – 5.00
	15	4.04 (0.86)	3.76 (0.93)	3.90 (0.90)	1.20 – 5.00
	30	3.84 (0.97)	3.63 (0.97)	3.74 (0.96)	1.40 – 5.00
Athletic-ideal internalisation	1	3.26 (0.99)	2.94 (0.93)	3.10 (0.96)	1.00 – 4.80
	4	3.06 (1.22)	2.81 (0.99)	2.94 (1.10)	1.00 – 5.00
	15	3.17 (1.22)	2.59 (1.10)	2.87 (1.18)	1.00 – 5.00
	30	3.03 (1.13)	2.64 (1.09)	2.84 (1.11)	1.00 – 5.00

Table C.7

Spearman correlations between psychometric measurements on each day of testing.

Day	Psychometric	EDEQ Global	BSQ	BDI
Day 1	BSQ	.80***	-	-
	BDI	.57***	.53***	-
	RSES	-.50**	-.36***	-.72***
	Thin	.42*	.29	.49**
	Athletic	.39*	.18	.13
Day 4	BSQ	.81***	-	-
	BDI	.37*	.48**	-
	RSES	.43*	-.48***	-.79***
	Thin	.55***	.39*	.42*
	Athletic	.52***	.33*	.00
Day 15	BSQ	.83***		-
	BDI	.41*	.49**	-
	RSES	-.41*	-.40*	-.72***
	Thin	.64***	.53***	.41*
	Athletic	.55***	.37*	-.01
Day 30	BSQ	.80***	-	-
	BDI	.44*	.40*	-
	RSES	-.52***	-.45*	-.71***
	Thin	.63***	.49**	.39*
	Athletic	.43*	.31	.06

Abbreviations. Thin = Thin Ideal Internalisation, Athletic = Athletic Ideal Internalisation

* $p < .05$, ** $p < .01$, *** $p < .001$

Principal Component Analysis (PCA)

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.85, indicating that the sampling was adequate for conducting a PCA. Bartlett's test of sphericity was statistically significant ($X^2(36) = 879.70$, $p < .001$). Two PCs had Eigenvalues greater than Kaiser's criterion of 1, suggesting two factors should be retained. Cattel's criterion, using the point of inflexion from a Scree plot, indicated that one factor should be retained. This was corroborated using Parallel analysis, which also indicated that one factor should be retained. Therefore, a PCA with one factor using Varimax rotation was conducted. The overall root mean square of the residuals was 0.12 ($p < .001$), indicating that the factor structure explained a reasonable proportion of the correlations. The fit based upon off diagonal values was 0.94. Table C.8 presents factor loadings for each psychometric measure onto the PC, referred to as 'psych' (a combination of body concerns, eating disorder psychopathology, self-esteem, and mood). Higher scores indicate increased concerns/psychopathology and lower self-esteem.

Table C.8

The PCA factor loadings on 'psych' for each psychometric measure.

Psychometric Measure	'psych'
EDE-Q Restraint	0.71
EDE-Q Eating	0.80
EDE-Q Shape	0.91
EDE-Q Weight	0.85
RSES	-0.66
BDI	0.63
BSQ	0.85
Thin Ideal Internalisation	0.68
Athletic Ideal Internalisation	0.49

Linear Mixed-Effects Model of Psychological Concerns

A full summary of the linear mixed-effects model of psychological concerns is presented in Table C.9.

Table C.9

Summary table of the linear mixed-effects model of psychological concerns.

Fixed Effects	*b* Coefficient	*b SE*	*CI*	*t*	*p*
(Intercept)	0.20	0.23	-0.24 – 0.64	0.87	.388
Condition	0.16	0.32	-0.48 – 0.80	0.50	.619
Day [4]	-0.42	0.12	-0.65 – -0.18	-3.45	.001
Day [15]	0.52	0.12	-0.75 – -0.29	-4.31	< .001
Day [30]	-0.38	0.12	-0.61 – -0.15	-3.17	.002
Condition X Day [4]	0.02	0.17	-0.31 – 0.35	0.12	.908
Condition X Day [15]	0.28	0.17	-0.05 – 0.62	1.66	.101
Condition X Day [30]	0.12	0.17	-0.20 – 0.45	0.73	.466
Random Effect	*SD*	Residual			
Participant ID (n = 38)	0.90	0.36			
Observations	151				
Log-Likelihood	-122.19				
AIC	264.38				
BIC	294.56				

Interactive 3D Body Size/Shape Estimations (Measurements)

Perceived Body Shape and BID

Descriptive statistics of participants perceived body size and shape and BID are presented in Table C.10 and below exploratory analyses are reported.

Table C.10

Descriptive statistics (mean and standard deviation) of the participant's perceived current body size/shape and BID, for each condition and day.

Variables	Intervention		Controls	
	Day 1	Day 30	Day 1	Day 30
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)
		Current		
BMI	26.83 (5.79)	25.25 (5.08)	26.16 (5.15)	25.36 (4.95)
WHR	0.77 (0.04)	0.77 (0.04)	0.77 (0.05)	0.76 (0.04)
WBR	0.85 (0.07)	0.84 (0.07)	0.85 (0.07)	0.84 (0.06)
BHR	0.90 (0.05)	0.92 (0.04)	0.90 (0.05)	0.91 (0.04)
		BID		
BMI	-1.29 (3.81)	-2.76 (3.28)	-2.25 (3.72)	-3.04 (3.42)
WHR	-0.07 (0.07)	-0.05 (0.07)	-0.03 (0.05)	-0.03 (0.05)
WBR	-0.06 (0.09)	-0.06 (0.09)	-0.03 (0.06)	-0.04 (0.07)
BHR	0.02 (0.06)	0.00 (0.05)	0.00 (0.07)	-0.01 (0.05)

There were significant positive correlations between perceived and actual BMI ($r_s = .83$, $p < .001$) for the whole sample at both time points (day 1, $r_s = .83$, $p < .001$; day 30, $r_s = .85$, $p < .001$). For the control group, there was a significant positive correlation between perceived and actual BMI ($r_s = .78$, $p < .001$) at both time points (day 1, $r_s = .75$, $p < .001$; day 30, $r_s = .79$, $p < .001$). For the intervention group, there was a significant positive correlation between perceived and actual BMI ($r_s = .75$, $p < .001$) at both time points (day 1, $r_s = .74$, $p < .001$; day 30, $r_s = .79$, $p < .001$). This suggests that as actual BMI increased, as did perceived BMI (see Figure 3.8, Chapter 3). There was a significant positive correlation between perceived BMI at day 1 and day 30 (whole sample, $r = .87$, $p < .001$; controls, $r = .82$, $p < .001$; intervention, $r = .92$, $p < .001$).

There was a significant negative correlation between BMI BID and actual BMI for the whole sample ($r_s = -.37$, $p = .001$) (day 1, $r_s = -.37$, $p = .025$; day 30, $r_s = -.35$, $p = .029$). For the control group, there was a significant negative correlation between BMI BID and actual BMI ($r_s = -.41$, $p = .011$), which was no longer significant when considering each day separately (day 1, $r_s = -.45$, $p = .054$; day 30, $r_s = -.38$, $p > .05$). For the intervention group, there was a significant positive correlation between BMI BID and actual BMI ($r_s = -.42$, $p = .008$), which was no longer significant when looking at each day separately (day 1, $r_s = -.42$, $p > .05$; day 30, $r_s = -.40$, $p > .05$).

There was a significant positive correlation between perceived and actual WHR ($r_s = .31$, $p < .001$) for the whole sample, which only remained significant for day 30 when looking at each day separately (day 1, $r_s = .21$, $p > .05$; day 30, $r_s = .38$, $p = .018$). For the control group, there was a significant positive correlation between perceived and actual BMI ($r_s = .39$, $p = .017$), which was no longer significant when considering each day separately (day 1, $r_s = .36$, $p > .05$; day 30, $r_s = .40$, $p > .05$). For the intervention group, there was no significant correlation between perceived and actual WHR ($r_s = .24$, $p > .05$) at either time point (day 1, $r_s = .05$, $p > .05$; day 30, $r_s = .36$, $p > .05$). There was a significant positive correlation between perceived WHR at day 1 and day 30 (whole sample, $r_s = .70$, $p < .001$; controls, $r_s = .69$, $p < .001$; intervention, $r_s = .71$, $p < .001$). A 2 (Day: 1 vs 30) X 2 (Condition: Intervention vs Controls) mixed ANOVA revealed that there was no significant effect of day or condition on perceived WHR (ps $> .05$).

There was a significant positive correlation between perceived and actual WBR ($r_s = .35$, $p = .002$) for the whole sample, which only remained significant for day 30 when considering each day separately (day 1, $r_s = .28$, $p > .05$; day 30, $r_s = .39$, $p = .016$). For the control group, there was a significant positive correlation between perceived and actual WBR ($r_s = .45$, $p = .006$), which only remained significant for day 1 (day 1, $r_s = .51$, $p = .029$; day 30, $r_s = .39$, $p > .05$). For the intervention group, there was no significant correlation between perceived and actual WBR ($r_s = .30$, $p > .05$) at either time points (day 1, $r_s = .06$, $p > .05$; day 30, $r_s = .42$, $p > .05$). There was a significant positive correlation between perceived WBR at day 1 and day 30 (whole sample, $r_s = .85$, $p < .001$; controls, $r_s = .81$, $p < .001$; intervention, $r_s = .86$, $p < .001$). A 2 X 2 mixed ANOVA revealed that there was no significant effect of day or condition on perceived WBR (*p*s > .05).

There was no significant correlation between perceived and actual BHR for the whole sample when considering both time points ($r_s = .12$, $p > .05$) or day 1 separately ($r_s = -.02$, $p > .05$), but there was a significant positive correlation on day 30 ($r_s = .34$, $p = .038$). For the control group, there were no significant association between perceived and actual BHR ($r_s = -.05$, $p > .05$) (day 1, $r_s = -.17$, $p > .05$; day 30, $r_s = .16$, $p > .05$). For the intervention group, there was no significant correlation between perceived and actual BHR ($r_s = .29$, $p > .05$) at either time points (day 1, $r_s = .19$, $p > .05$; day 30, $r_s = .49$, $p = .032$). There was a significant positive correlation between perceived BHR at day 1 and day 30 (whole sample, $r_s = .70$, $p < .001$; controls, $r_s = .62$, $p = .006$; intervention, $r_s = .68$, $p = .002$). A 2 (Day: 1 vs 30) X 2 (Condition: Intervention vs Controls) mixed ANOVA revealed that there was no significant effect of day or condition on perceived BHR (*p*s > .05).

Ideal Body Shape and BD

Descriptive statistics for participant’s ideal body size/shape and BD are presented in Table C.11 and exploratory analyses are reported.

Table C.11

Descriptive statistics (mean and standard deviation) of the participants' ideal body size/shape and perceptual BD, for each condition and day.

Variables	Intervention		Controls	
	Day 1	Day 30	Day 1	Day 30
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)
		Ideal		
BMI	20.27 (2.95)	20.84 (3.39)	20.16 (3.04)	20.16 (3.03)
WHR	0.69 (0.04)	0.71 (0.05)	0.70 (0.04)	0.71 (0.03)
WBR	0.75 (0.04)	0.76 (0.05)	0.75 (0.04)	0.75 (0.03)
BHR	0.93 (0.03)	0.93 (0.02)	0.94 (0.03)	0.95 (0.02)
		BD		
BMI	-6.56 (4.37)	-4.41 (2.64)	-6.00 (4.15)	-5.21 (3.39)
WHR	-0.08 (0.04)	-0.07 (0.04)	-0.07 (0.05)	-0.06 (0.04)
WBR	-0.11 (0.06)	-0.09 (0.05)	-0.10 (0.07)	-0.09 (0.05)
BHR	0.02 (0.04)	0.02 (0.04)	0.03 (0.05)	0.03 (0.03)

There were significant positive correlations between ideal and actual BMI (r_s = .68, p < .001) for the whole sample at both time points (day 1, r_s = .61, p < .001; day 30, r_s = .74, p < .001). For the control group, there was a significant positive correlation between ideal and actual BMI (r_s = .75, p < .001) at both time points (day 1, r_s = .71, p < .001; day 30, r_s = .79, p < .001). For the intervention group, there was a significant positive correlation between ideal and actual BMI (r_s = .52, p < .001) at both time points (day 1, r_s = .45, p < .001; day 30, r_s = .58, p < .001). This suggests that as actual BMI increased, as did ideal BMI.

There were significant negative correlations between BMI BD (the discrepancy between perceived and ideal BMI) and actual BMI for the whole sample ($r_s = -.55$, $p < .001$) at both time points (day 1, $r_s = -.56$, $p < .001$; day 30, $r_s = -.59$, $p < .001$). For the control group, there was a significant negative correlation ($r_s = -.39$, $p = .016$), which was not significant when considering each both time points separately (day 1, $r_s = -.38$, $p > .05$; day 30, $r_s = -.35$, $p > .05$). For the intervention group, there were significant negative correlations ($r_s = -.66$, $p < .001$) at both time points (day 1, $r_s = -.66$, $p = .003$; day 30, $r_s = -.76$, $p < .001$). This suggests that as actual BMI increased, the discrepancy between perceived and ideal BMI became increasingly negative, indicating a desire for an ideal body size smaller than the perceived current body size.

The consistency between sessions was determined using correlations. There was a significant positive correlation between ideal BMI at day 1 and day 30 (whole sample, $r = .80$, $p < .001$; controls, $r = .87$, $p < .001$; intervention, $r = .75$, $p < .001$). There was a significant positive correlation between ideal WHR at day 1 and day 30 (whole sample, $r = .65$, $p < .001$; controls, $r = .71$, $p < .001$; intervention, $r = .62$, $p = .004$). There was a significant positive correlation between ideal WBR at day 1 and day 30 (whole sample, $r = .73$, $p < .001$; controls, $r = .81$, $p < .001$; intervention, $r = .69$, $p < .001$). There was a significant positive correlation between ideal BHR at day 1 and day 30 for the whole sample ($r = .41$, $p = .011$), which were no longer significant when considering the groups separately (controls, $r = .42$, $p > .05$; intervention, $r = .31$, $p > .05$).

A 2 (Day: 1 vs 30) X 2 (Condition: Intervention vs Controls) mixed ANOVA for ideal BHR revealed that there was a significant main effect of condition, where the intervention group desired a significantly lower BHR ($M = 0.93$, $SD = 0.03$) than the control group ($M = 0.94$, $SD = 0.04$) ($F(1,72) = 5.04$, $p = .028$), but there was no significant main effect of day or condition x day interaction. A series of 2 X 2 mixed ANOVAs indicated that there were no main effects of condition or day or interaction on ideal WHR/WBR/BHR BD (all *p*s $> .05$), suggesting that levels of BD did not differ between groups or sessions.

Appendix D

Supplementary and exploratory analyses for Study 2 are presented here.

Psychometric Measures

The descriptive statistics of all psychometrics measures are presented in Table D.1. There were significant differences between the high and low concerns groups on all psychometric measures, except the athletic ideal internalisation SATAQ-4 subscale (see Table D.1), indicating that the high concerns group reported higher disordered eating symptomology, depressive symptoms, internalisation of a thin ideal, and lower self-esteem than the low concerns group, supporting group differences in attitudinal body image and broader psychological concerns.

Table D.1

Descriptive statistics (mean, standard deviation, and range) for each measure/subscale and statistical differences between groups.

	High Concerns	Low Concerns	Overall		High vs low
Psychometric Measure	*M* (SD)	*M* (SD)	*M* (SD)	Range	*p*
EDE-Q Res	2.44 (1.20)	1.14 (1.07)	1.86 (1.31)	0.00 – 5.00	< .001
EDE-Q Eat	2.44 (1.38)	0.85 (1.08)	1.74 (1.48)	0.00 – 6.00	< .001
EDE-Q Shape	4.26 (1.14)	2.20 (1.45)	3.35 (1.64)	0.00 – 6.00	< .001
EDE-Q Weight	3.73 (0.98)	1.76 (1.32)	2.86 (1.50)	0.00 – 5.40	< .001
EDE-Q Global	3.22 (0.95)	1.49 (1.11)	2.45 (1.34)	0.00 - 5.45	< .001
RSES Total	15.16 (5.11)	17.97 (5.01)	16.40 (5.22)	4.00 – 30.00	.019
BDI Total	14.50 (8.79)	7.83 (6.63)	11.56 (8.53)	0.00 – 41.00	< .001
BSQ Total	69.08 (12.71)	40.03 (12.06)	56.26(19.06)	20.00 – 93.00	< .001
Thin Ideal	3.81 (0.75)	2.88 (0.83)	3.40 (0.91)	1.20 – 5.00	< .001
Athletic Ideal	3.10 (0.96)	2.73 (1.19)	2.94 (1.07)	1.00 – 5.00	> .05

Abbreviations. EDE-Q Res = EDE-Q Dietary Restraint, EDE-Q Eat = EDE-Q Eating Concerns, EDE-Q Shape = EDE-Q Shape Concerns, EDE-Q Weight = EDE-Q Weight Concerns.

To determine consistency between the BSQ scores (from the psychometric measures taken in the lab testing session, reported above in Table D.1) and the pre-screening BSQ scores Spearman's rank correlations were conducted. The results indicated significant correlations between the two BSQ scores (whole sample, $r_s = .84$, $p < .001$; high concerns, $r_s = .48$, $p = .002$; low concerns, $r_s = .78$, $p < .001$). A two-way random intraclass correlation for absolute agreement between the two time points revealed significant agreement between BSQ scores at pre-screening and in the testing session (ICC(68, 2) = 0.86; 95%CI [0.78 – 0.91], $p < .001$), which exceeds the 0.70 criterion (Nunnally, 1978) and the more conservative 0.80 criterion (Carmines, 1990).

Spearman's correlations were conducted to identify whether there was multi-collinearity between psychometric measures taken in the lab, displayed in Table D.2.

Table D.2

The relationship between psychometric measures.

	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. EDE-Q Restraint	.66***	.68***	.63***	.79***	-.28*	.52***	.68***	.62***	.53***
2. EDE-Q Eating		.81***	.78***	.90***	-.41***	.68***	.74***	.51***	.23
3. EDE-Q Shape			.89***	.94***	-.54***	.76***	.89***	.62***	.25*
4. EDE-Q Weight				.92***	-.53***	.70***	.86***	.54***	.19
5. EDE-Q Global					-.49***	.72***	.88***	.62***	.30*
6. RSES						-.73***	-.48***	-.26*	-.06
7. BDI							.69***	.53***	.18
8. BSQ								.59***	.28*
9. Thin Ideal									.36**
10. Athletic Ideal									-

* $p < .05$, ** $p < .01$, *** $p < .001$

Principal Components Analysis (PCA)

Given the substantial correlations between many of the psychometric scores, a PCA was used to identify significant latent variable/s in the psychometric data, for the whole sample. The EDE-Q Global score was omitted from this analysis, as the four subscale scores were used, resulting in a total of nine variables in the PCA. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.87, indicating that the sampling was adequate for conducting a PCA. Bartlett's test of sphericity was statistically significant ($X^2(36) = 504.73$, $p < .001$). Two PCs had Eigenvalues greater than Kaiser's criterion of 1, suggesting two factors should be retained. Cattel's criterion, using the point of inflexion from a Scree plot, indicated that one factor should be retained. This was corroborated using Parallel analysis, which also indicated that one factor should be retained. Therefore, a PCA with one factor using Varimax rotation was conducted. The overall root mean square of the residuals was 0.10 ($p < .005$), indicating that the factor structure explained a reasonable proportion of the correlations. The fit based upon off diagonal values was 0.97, exceeding the 0.95 criterion. The factor loadings are reported in Table D.3. 'Psych' was significantly positively correlated with all psychometric measures (n = 68, all *p*s < .004). The factor scores for 'psych' were for analyses in Study 2.

Table D.3

The PCA factor loadings on 'psych' for each psychometric measure.

Psychometric Measure	'psych'
EDE-Q Restraint	0.81
EDE-Q Eating	0.84
EDE-Q Shape	0.94
EDE-Q Weight	0.90
RSES	-0.65
BDI	0.80
BSQ	0.91

Psychometric Measure	'psych'
Thin Ideal Internalisation	0.71
Athletic Ideal Internalisation	0.35

Spearman's rank correlations were used to explore the relationship between 'psych' and participant characteristics in the whole sample. There was a significant negative correlation between 'psych' and age (r_s = -.25, p = .044) and significant positive correlations between 'psych' and BMI (r_s = .33, p = .007), WHR (r_s = .31, p = .010), and WBR (r_s = .38, p = .001). This indicates that increases in psychological concerns are associated with increases in BMI, WHR and WBR, and a decrease in age. When considering only the high concerns group, 'psych' was not significantly correlated with any participant characteristics (ps > .05). For the low concerns group, 'psych' was significantly positively correlated with WBR (r_s = .37, p = .043), but no other participant characteristics (ps > .05).

Interactive 3D Body Size/Shape Estimates (Measurements)

Exploratory analyses looking at the relationship between perceived and actual body size/shape for high and low concerns groups were conducted. Spearman's Rank correlations were used to look at the relationship between perceived current and actual body size/shape for each variable. The results revealed that there were significant positive correlations between perceived current and actual BMI, WHR, and WBR for the whole sample and for the low concerns group. For the high concerns group, only the relationship between perceived current and actual BMI was significant. The relationship between perceived and actual BHR was not significant for the whole sample or the groups individually. The strong positive correlation between actual and perceived BMI indicates good consistency between the participant's actual body size/shape and the perceptions of their own body size/shape, for both groups. See Table D.4 for correlation coefficients. Wilcoxon Signed-Ranks Tests were conducted to identify significant differences between perceived current and actual body measurements – the significance values are presented in Table D.4. Actual BMI and perceived BMI were not significantly different for the high concerns group, indicating that they were, on average, accurate at estimating their own body size.

Table D.4

The relationship between actual and perceived current body size/shape.

	BMI		WHR		WBR		BHR	
	r_s	p	r_s	p	r_s	p	r_s	p
Whole Sample	.86***	.021	.47***	< .001	.58***	< .001	.07	> .05
High Concerns	.83***	> .05	.21	< .001	.28	.003	-.02	> .05
Low Concerns	.78***	.008	.68***	.006	.69***	< .001	.21	.025

Note. Here, the p values refer to the Wilcoxon Signed-Ranks Tests determining whether there were significant differences between actual and perceived measurements. Asterisks denote the significance value of the correlations between actual and perceived measurements, * $p < .05$, ** $p < .01$, *** $p < .001$

Correlations between Daz PC scores and Daz Body Size/Shape Measurements

The measurements taken from the Daz bodies (BMI, WHR, WBR, and BHR) were correlated with scores from the PCA of the Daz body shapes, to identify relationships between measurements and factor scores (see Table D.5). There were significant correlations between body size/shape measurements and perceived current and ideal PC1, indicating that PC1 captures overall size/shape. Full descriptions of each PC are reported in Study 2, Chapter 3.

Table D.5

Spearman's correlations between body size/shape measurements and PC factor scores for both perceived current and ideal, for the whole sample.

	Perceived BMI	Perceived WHR	Perceived WBR	Perceived BHR
CurrentPC1	.98***	.65***	.84***	-.67***
CurrentPC2	.02	-.08	-.27*	.26*
CurrentPC3	-.06	-.01	.16	-.22
CurrentPC4	-.16	.11	-.08	.17
	Ideal BMI	Ideal WHR	Ideal WBR	Ideal BHR
IdealPC1	.96***	.52***	.74***	-.40**
IdealPC2	.07	.03	-.14	.32**
IdealPC3	-.15	.12	.19	-.18
IdealPC4	-.20	.20	.08	.14

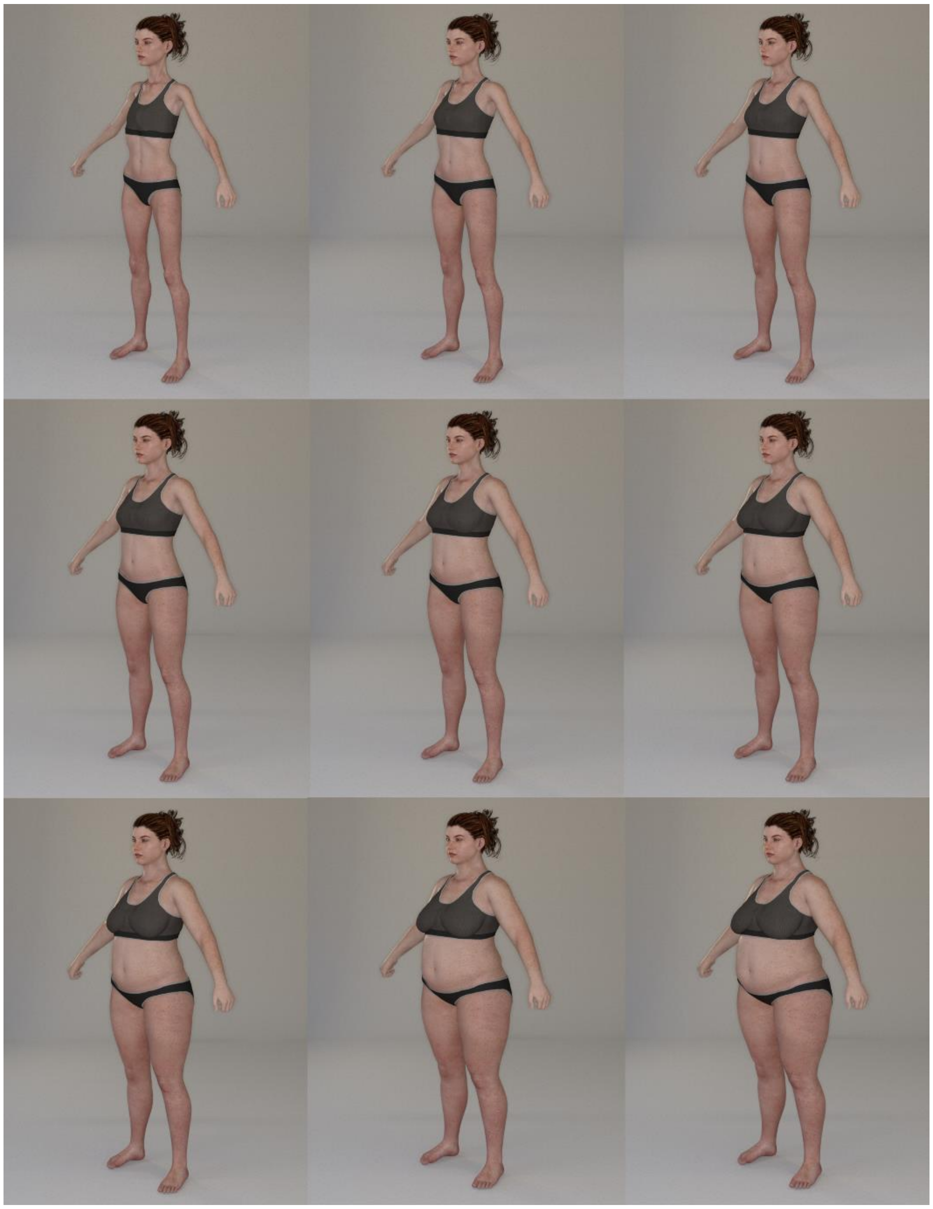
* $p < .05$, ** $p < .01$, *** $p < .001$

Appendix E

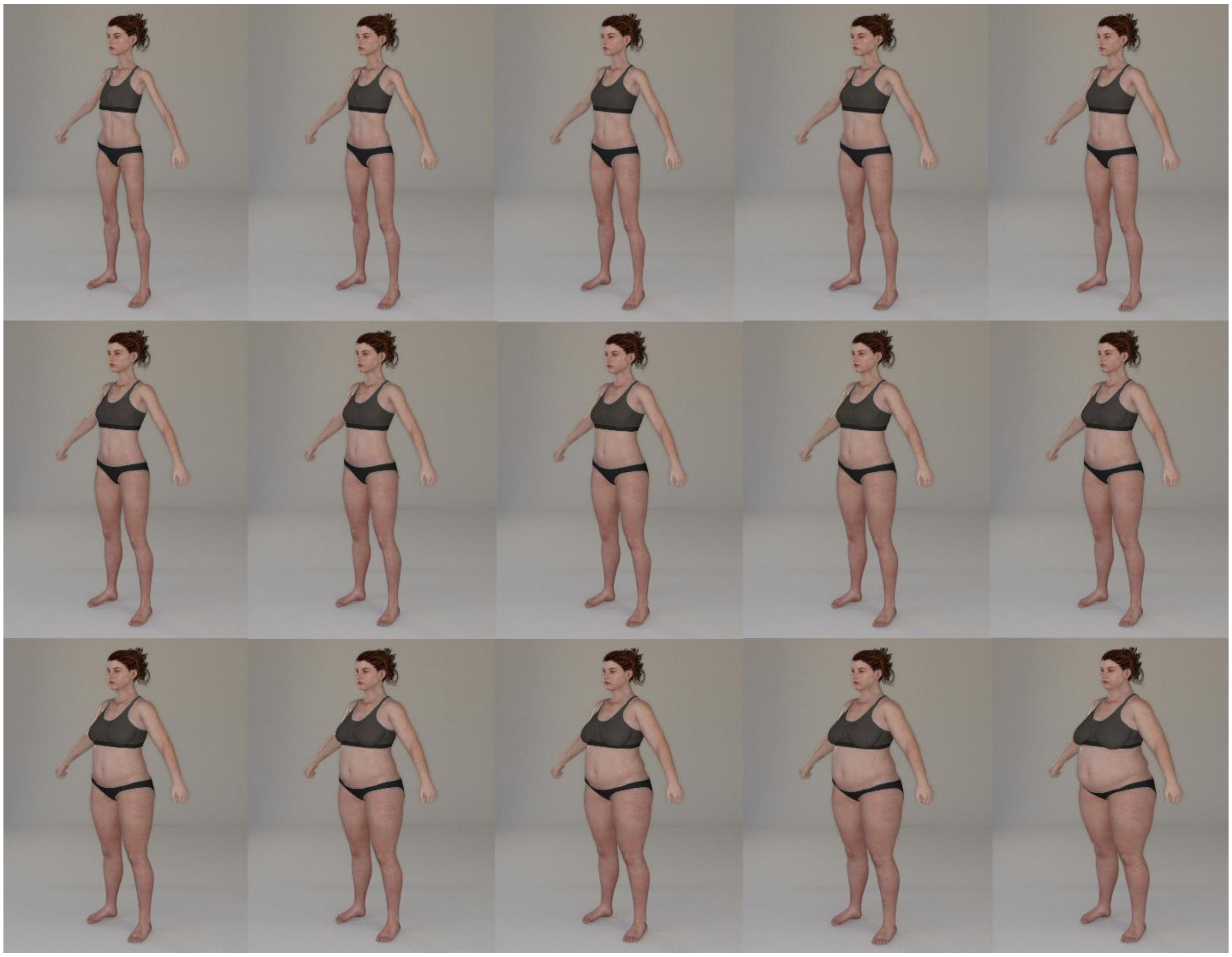
Here, the stimuli and the supplementary/exploratory analyses for Study 4 are presented.

Images of the two Just Noticeable Difference discrete body scales used in Study 4 are presented below.

Nine-item FRS (FRS-9)



Fifteen-item FRS (FRS-15)



Psychometric Measures

Scores from psychometric measures from Study 4 were checked for multi-collinearity using Spearman's Rank correlations. There were significant (moderate to strong) positive correlations ($r_s > .31$) between scores on the psychometric measures from Study 4, displayed in Table E.1.

Table E.1

The relationship between psychometric measures.

Psychometrics	EDE-Q Restraint	EDE-Q Eating	EDE-Q Shape	EDE-Q Weight	EDE-Q Global	RSES	BDI	BSQ	Thin Ideal
EDE-Q Eating	.69***								
EDE-Q Shape	.80***	.79***							
EDE-Q Weight	.82***	.83***	.95***						
EDE-Q Global	.89***	.88***	.96***	.98***					
RSES	-.39**	-.54***	-.59***	-.56***	-.56***				
BDI	.41**	.58***	.61***	.60***	.60***	-.73***			
BSQ	.80**	.85***	92***	.92***	.94***	-.56***	.61***		
Thin Ideal	.61***	.49***	.69***	.67**	.67***	-.51***	.39**	.61***	
Athletic Ideal	.44**	.31*	.45**	.41**	.44**	-.27*	.27*	.44**	.42**

Abbreviations. Thin Ideal = SATAQ-4 Thin Ideal Internalisation, Athletic Ideal = SATAQ-4 Athletic Ideal Internalisation, *** $p < .001$, ** $p < .005$, * $p < .05$

The relationship between psychometric scores and BMI for the whole sample (session 1, n = 48) was assessed using Spearman's Rank correlations. Scores on the EDE-Q Dietary Restraint ($r_s = .36$, $p = .012$), EDE-Q Shape Concerns ($r_s = .31$, $p = .032$), EDE-Q Weight Concerns subscales ($r_s = .40$, $p = .005$), EDE-Q Global ($r_s = .36$, $p = .011$), and BSQ ($r_s = .31$, $p = .035$) were significantly positively correlated with participant's actual BMI. No associations between EDE-Q Eating Concerns, RSES, BDI, or SATAQ-4 Thin and Athletic Ideal Internalisation scores and BMI were found (all *p*s > .05).

Appendix F

The supplementary and exploratory analyses for Study 5 are presented here.

Psychometric Measures

Saphiro-Wilks tests of normality indicated that the psychometric data were not normally distributed ($p < .05$) therefore, non-parametric Spearman's correlations were conducted to identify whether there was multi-collinearity between psychometric measures, displayed in Table F.1.

Table F.1

The relationship between psychometric measures.

	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. EDE-Q Restraint	.49***	.56***	.52***	.72***	-.15*	.20**	.54***	.38***	.24***	.38***	.06	.42***	.04
2. EDE-Q Eating		.69***	.69***	.78***	-.37***	.45***	.71***	.43***	.10	.62***	.02	.49***	-.02
3. EDE-Q Shape			.92***	.95***	-.49***	.54***	.83***	.54***	.07	.81***	-.00	.70***	-.02
4. EDE-Q Weight				.93***	-.43***	.49***	.82***	.48***	.05	.83***	-.03	.65**	-.05
5. EDE-Q Global					-.43***	.49***	.84***	.53***	.13*	.77***	.00	.66***	-.02
6. RSES						-.71***	-.51***	-.33***	.03	-.62***	.03	-.43***	.14
7. BDI							.54***	.40***	-.04	.59***	-.01	.41***	-.04
8. BSQ								.51***	.00	.80***	.01	.72***	-.07
9. Thin Ideal									.25***	.47***	.21**	.50***	.09
10. Athletic Ideal										-.05	.18**	.12*	.27***
11. WBIS-M											-.03	.60***	-.10
12. AFA Dislike												.23**	.57***
13. AFA Fear of Fat													.16*
14. AFA Willpower													--

*** $p < .001$, ** $p < .005$, * $p < .05$

Principal Component Analysis (PCA)

Given the substantial correlations between many of the psychometric variables in Study 5 (Table F.1), a PCA was used to identify significant latent variable/s in the psychometric data, for the whole sample. The EDE-Q Global score was omitted from this analysis, as the four subscale scores were used, resulting in a total of thirteen variables in the PCA. The factor scores from the latent variable/s were then used in statistical analyses in Chapter 5.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.87, indicating that the sampling was adequate for conducting a PCA. Bartlett's test of sphericity was statistically significant ($X^2(78) = 2070.96$, $p < .001$). Three PCs had Eigenvalues greater than Kaiser's criterion of 1, suggesting three factors should be retained. Cattel's criterion, using the point of inflexion from a Scree plot, indicated that two factors should be retained. This was corroborated using Parallel analysis which also indicated that two factors should be retained. Therefore, a PCA with two factors using Varimax rotation was conducted. The overall root mean square of the residuals was 0.08 ($p < .001$), indicating that the factor structure explained a reasonable proportion of the correlations. The fit based upon off diagonal values was 0.97, exceeding the 0.95 criterion.

The factor loadings are presented in Table F.2. The first latent factor represents psychological concerns (a combination of attitudes related to body image and negative attitudes towards the self, e.g. disturbed attitudes to eating, body dissatisfaction and negative affect), henceforth referred to as 'psych'. Higher scores indicate higher depressive symptoms, lower self-esteem, higher dietary restraint, a fear of becoming fat and body/weight/shape concerns. The second latent factor represents an expression of anti-fat attitudes and the internalisation of an athletic physique ideal, henceforth referred to as ‘fat attitudes’. Higher scores indicate higher anti-fat attitudes and athletic-ideal internalisation.

Table F.2

The PCA factor loadings on ‘psych’ and ‘fat attitudes’ for each psychometric measure.

Psychometric Measure	‘psych’	‘fat attitudes’
EDE-Q Restraint	0.60	
EDE-Q Eating	0.80	
EDE-Q Shape	0.90	
EDE-Q Weight	0.90	
RSES	-0.70	
BDI	0.70	
BSQ	0.90	
Thin Ideal Internalisation	0.60	
WBIS-M	0.90	
AFA Fear of Fat	0.80	
AFA Dislike		0.80
AFA Willpower		0.80
Athletic Ideal Internalisation		0.60

The relationships between participant characteristics and the latent variables were explored. Spearman’s rank correlations revealed significant positive correlations between ‘psych’, BMI (r_s = .27, p < .001, n = 225), self-perceived BMI weight status (r_s = .29, p < .001, n = 227), and age (r_s = -.21, p = .002, n = 227), indicating that an increase in BMI is associated with increases in body concerns/negative affect, whereas an increase in age is associated with decreases in body concerns/negative affect. There was a significant negative correlation between 'fat attitudes', self-perceived BMI weight status (r_s = -.15, p = .028, n = 227) but not with BMI (r_s = -.08, p > .05, n = 225) or age (r_s = .12, p > .05, n = 227). This indicates that increases in self-perceived weight status are associated with decreases in anti-fat attitudes/athletic ideal internalisation.

Independent samples t-tests indicated that there were significant differences between male and female participants for 'psych' (t(222.48) = -5.92, p = .001) and 'fat attitudes' (t(209.98) = 5.61, p < .001). This indicates that, on average, females score higher on the factor reflecting to body concerns/negative affect and males score higher on the factor reflecting anti-fat attitudes/athletic ideal internalisation.

Linear Mixed-Effects Model of BMI Category Accuracy

A summary of the model is presented in Table F.3

Table F.3

Summary table of the mixed-effect linear model of accuracy.

Fixed Effects	*b* Coefficient	*b* SE	CI	*t*	*p*
(Intercept)	1.44	0.26	0.93 – 1.95	5.52	< .001
Stimulus BMI	-0.06	0.01	-0.08 – -0.04	-6.32	< .001
Participant Sex	0.29	0.06	0.18 – 0.40	5.03	< .001
'psych'	-0.08	0.05	-0.17 – 0.01	-1.73	.083
'fat attitudes'	-0.04	0.04	-0.11 – 0.04	-0.94	.348
Viewpoint	-0.07	0.04	-0.16 – 0.02	-1.56	.120
Stimulus BMI X Participant Sex	-0.01	0.00	-0.01 – -0.01	-4.48	< .001

Fixed Effects	*b* Coefficient	*b* SE	CI	*t*	*p*
Stimulus BMI X ‘psych’	0.00	0.00	0.00 – 0.01	2.09	.036
Stimulus BMI X ‘fat attitudes’	0.00	0.00	0.00 – 0.01	2.68	.007
Stimulus BMI X Viewpoint	0.00	0.00	-0.00 – 0.01	1.62	.104
Participant Sex X ‘psych’	-0.07	0.06	-0.18 – 0.04	-1.18	.236
Participant Sex X ‘fat attitudes’	-0.02	0.06	-0.13 – 0.09	-0.34	.736
Participant Sex X Viewpoint	0.13	0.06	0.01 – 0.25	2.14	.033
‘psych’ X ‘fat attitudes’	0.06	0.04	-0.01 – 0.14	1.62	.106
‘psych’ X Viewpoint	-0.20	0.05	0.29 – -0.10	-4.10	< .001
‘fat attitudes’ X Viewpoint	-0.06	0.04	-0.13 – 0.02	-1.42	.154
Stimulus BMI X Participant Sex X ‘psych’	-0.00	0.00	-0.00 – 0.01	1.77	.076
Stimulus BMI X Participant Sex X ‘fat attitudes’	-0.00	0.00	-0.00 – 0.01	1.71	.087
Stimulus BMI X ‘psych’ X ‘fat attitudes’	-0.00	0.00	-0.01 – -0.00	-2.67	.008
Stimulus BMI X Participant Sex X Viewpoint	-0.00	0.00	-0.01 – -0.00	-1.97	.049
Stimulus BMI X ‘psych’ X Viewpoint	0.01	0.00	0.00 – 0.01	4.09	< .001
Stimulus BMI X ‘fat attitudes’ X Viewpoint	0.00	0.00	-0.00 – 0.00	1.25	.213
Participant Sex X ‘psych’ X ‘fat attitudes’	-0.07	0.05	-0.17 – 0.04	-1.24	.217
Participant Sex X ‘psych’ X Viewpoint	0.23	0.06	0.11 – 0.35	3.85	< .001
Participant Sex X ‘fat attitudes’ X Viewpoint	0.09	0.06	-0.03 – 0.20	1.49	.136
‘psych’ X ‘fat attitudes’ X Viewpoint	-0.09	0.04	-0.17 – -0.00	-2.04	.041

Fixed Effects	*b* Coefficient	*b* SE	CI	*t*	*p*
Stimulus BMI X Participant Sex X ‘psych’ X ‘fat attitudes’	0.00	0.00	-0.00 – 0.01	1.71	.088
Stimulus BMI X Participant Sex X ‘psych’ X Viewpoint	-0.01	0.00	-0.01 – -0.00	-3.97	< .001
Stimulus BMI X Participant Sex X ‘psych’ X Viewpoint	-0.00	0.00	-0.01 – 0.00	-1.35	.178
Stimulus BMI X ‘psych’ X ‘fat attitudes’ X Viewpoint	0.00	0.00	0.00 – 0.01	2.15	.031
Participant Sex X ‘psych’ X ‘fat attitudes’ X Viewpoint	0.03	0.06	-0.07 – 0.14	0.61	.540
Stimulus BMI X Participant Sex X ‘psych’ X ‘fat attitudes’ X Viewpoint	-0.00	0.00	-0.01 – 0.00	-0.75	.452
Random Effect	SD	Residual			
Stimulus ID (n = 24)	0.32				
Response ID (n = 227)	0.30	0.33			
Observations	10,896				
Log-Likelihood	-6129.90				
AIC	12329.80				
BIC	12585.16				

Linear Mixed Effect Model of Attitudes to Weight Loss

A full summary of the model is presented in Table F.4.

Table F.4

Summary table of the mixed-effect linear model of attitudes to weight loss.

Fixed Effects	*b* Coefficient	b SE	CI	*t*	*p*
(Intercept)	-0.89	0.23	-1.34 – -0.45	-3.97	< .001
Stimulus BMI	0.15	0.01	0.13 – 0.16	16.86	< .001
Participant Sex	0.41	0.09	0.22 – 0.59	4.29	< .001
‘psych’	0.18	0.07	0.04 – 0.33	2.46	.014
‘fat attitudes’	0.04	0.06	-0.08 – 0.16	0.60	.546
Viewpoint	-0.01	0.06	-0.13 – 0.12	-0.10	.923
Stimulus BMI X Participant Sex	-0.01	0.00	-0.02 – -0.01	-3.76	< .001
Stimulus BMI X ‘psych’	-0.00	0.00	-0.01 – 0.00	-1.34	.180
Stimulus BMI X ‘fat attitudes’	0.01	0.00	0.00 – 0.01	2.42	.016
Stimulus BMI X Viewpoint	0.00	0.00	-0.00 – 0.01	0.27	.785
Participant Sex X ‘psych’	-0.20	0.09	-0.38 – -0.01	-2.09	.036
Participant Sex X ‘fat attitudes’	0.12	0.09	-0.06 – 0.30	1.35	.176
Participant Sex X Viewpoint	-0.02	0.09	-0.19 – 0.15	-0.24	.812
‘psych’ X ‘fat attitudes’	0.31	0.07	0.18 – 0.43	4.66	< .001
‘psych’ X Viewpoint	-0.09	0.07	-0.22 – 0.05	-1.29	.198
‘fat attitudes’ X Viewpoint	-0.05	0.06	-0.16 – 0.06	-0.88	.381
Stimulus BMI X Participant Sex X ‘psych’	0.01	0.00	0.00 – 0.01	2.07	.038
Stimulus BMI X Participant Sex X ‘fat attitudes’	0.00	0.00	-0.00 – 0.01	0.92	.360

Fixed Effects	*b* Coefficient	b SE	CI	*t*	*p*
Stimulus BMI X ‘psych’ X ‘fat attitudes’	-0.01	0.00	-0.02 – -0.01	-5.29	< .001
Stimulus BMI X Participant Sex X Viewpoint	0.00	0.00	-0.01 – 0.01	0.36	.721
Stimulus BMI X ‘psych’ X Viewpoint	0.00	0.00	-0.00 – 0.01	1.29	.196
Stimulus BMI X ‘fat attitudes’ X Viewpoint	0.00	0.00	-0.00 – 0.01	0.74	.458
Participant Sex X ‘psych’ X ‘fat attitudes’	-0.21	0.09	-0.38 – -0.04	-2.45	.014
Participant Sex X ‘psych’ X Viewpoint	0.13	0.09	-0.04 – 0.30	1.54	.124
Participant Sex X ‘fat attitudes’ X Viewpoint	0.10	0.08	-0.07 – 0.26	1.18	.240
‘psych’ X ‘fat attitudes’ X Viewpoint	-0.05	0.06	-0.17 – 0.07	-0.78	.435
Stimulus BMI X Participant Sex X ‘psych’ X ‘fat attitudes’	0.01	0.00	0.00 – 0.01	2.37	.018
Stimulus BMI X Participant Sex X ‘psych’ X Viewpoint	-0.01	0.00	-0.01 – 0.00	-1.53	.127
Stimulus BMI X Participant Sex X ‘fat attitudes’ X Viewpoint	-0.00	0.00	-0.01 – 0.00	-1.15	.251
Stimulus BMI X ‘psych’ X ‘fat attitudes’ X Viewpoint	0.00	0.00	-0.00 – 0.01	0.97	.331
Participant Sex X ‘psych’ X ‘fat attitudes’ X Viewpoint	-0.04	0.08	-0.19 – 0.12	-0.44	.660
Stimulus BMI X Participant Sex X ‘psych’ X ‘fat attitudes’ X Viewpoint	0.00	0.00	-0.01 – 0.01	0.31	.760
Random Effect	**SD**	**Residual**			
Stimulus ID (n = 24)	0.26				
Response ID (n = 227)	0.56	0.48			
Observations	10,896				
Log-Likelihood	-11204.52				
AIC	22479.04				

Fixed Effects	*b* Coefficient	b SE	CI	*t*	*p*
BIC	22734.30				

Appendix G

Supplementary and exploratory analyses for Study 6 are presented below.

Reported in Table G.1 are the means and standard deviations of fat and muscle ratings for each stimulus.

Table G.1

The means and standard deviation of fat and muscle ratings for each stimulus.

FATM level	SMM level	Fat Rating		Muscle Rating	
		M	SD	*M*	SD
1	1	1.83	0.88	4.54	1.69
1	2	1.80	0.85	4.49	1.53
1	3	1.89	0.90	4.25	1.55
1	4	1.82	0.85	4.46	1.63
1	5	1.63	0.84	4.71	1.72
2	1	2.80	1.13	4.25	1.31
2	2	2.58	0.97	4.34	1.19
2	3	2.37	0.96	4.51	1.37
2	4	2.26	0.92	4.37	1.49
2	5	2.20	0.89	4.68	1.34
3	1	3.83	0.96	3.89	1.11
3	2	3.38	0.93	3.82	1.25
3	3	3.05	1.02	4.08	1.30
3	4	2.88	1.04	4.35	1.35
3	5	2.91	1.09	4.77	1.26
4	1	4.35	0.89	3.34	1.02
4	2	4.17	0.93	3.63	1.21
4	3	3.83	0.89	3.86	1.13

FATM level	SMM level	Fat Rating		Muscle Rating	
		M	SD	*M*	SD
4	4	3.68	1.00	4.12	1.13
4	5	3.52	1.13	4.14	1.17
5	1	4.91	0.88	3.08	1.14
5	2	4.75	0.88	3.23	1.09
5	3	4.63	0.82	3.32	1.03
5	4	4.38	0.91	3.69	1.01
5	5	4.17	0.88	4.12	1.02
6	1	5.40	0.79	2.98	1.29
6	2	5.26	0.69	3.06	1.18
6	3	5.18	0.63	3.20	0.99
6	4	4.92	0.64	3.32	1.02
6	5	4.83	0.80	3.52	1.16
7	1	5.83	0.72	2.68	1.23
7	2	5.74	0.76	2.62	1.14
7	3	5.52	0.64	2.75	1.13
7	4	5.35	0.74	2.86	1.21
7	5	5.34	0.54	3.23	1.17
8	1	6.26	0.71	2.37	1.23
8	2	6.05	0.67	2.54	1.28
8	3	5.91	0.68	2.55	1.25
8	4	5.85	0.62	2.78	1.21
8	5	5.65	0.65	2.88	1.22
9	1	6.60	0.55	2.32	1.26
9	2	6.51	0.53	2.35	1.22
9	3	6.26	0.64	2.66	1.29
9	4	6.20	0.62	2.55	1.21
9	5	6.11	0.66	2.54	1.17

FATM level	SMM level	Fat Rating		Muscle Rating	
		M	SD	*M*	SD
10	1	6.77	0.72	2.18	1.38
10	2	6.63	0.52	2.37	1.35
10	3	6.55	0.56	2.37	1.29
10	4	6.46	0.61	2.48	1.36
10	5	6.31	0.66	2.51	1.32

Abbreviations. SMM = Skeletal Muscle Mass, FATM = Fat Mass. The corresponding values of FATM and SMM in kg for each level are presented in Table 6.1, Chapter 6.

In Study 6, the r_{wg} (a measure of interrater agreement) was calculated for each stimulus. The r_{wg} for fat ratings and muscle ratings for each stimulus are reported in Tables G.2 and G.3.

Table G.2

Interrater agreement for fat ratings for each level of FATM and SMM (i.e. each stimulus).

FATM level	SMM level	r_{wg} (n = 65)
1	1	0.81
1	2	0.82
1	3	0.80
1	4	0.82
1	5	0.82
2	1	0.68
2	2	0.77
2	3	0.77
2	4	0.79
2	5	0.80
3	1	0.77
3	2	0.78
3	3	0.74

FATM level	SMM level	r_{wg} (n = 65)
3	4	0.73
3	5	0.71
4	1	0.80
4	2	0.78
4	3	0.80
4	4	0.75
4	5	0.68
5	1	0.81
5	2	0.80
5	3	0.83
5	4	0.79
5	5	0.81
6	1	0.85
6	2	0.88
6	3	0.90
6	4	0.90
6	5	0.84
7	1	0.87
7	2	0.86
7	3	0.90
7	4	0.86
7	5	0.93
8	1	0.87
8	2	0.89
8	3	0.88
8	4	0.90
8	5	0.90
9	1	0.92
9	2	0.93
9	3	0.90

FATM level	SMM level	r_{wg} (n = 65)
9	4	0.90
9	5	0.89
10	1	0.87
10	2	0.93
10	3	0.92
10	4	0.91
10	5	0.89

Abbreviations. SMM = Skeletal Muscle Mass, FATM = Fat Mass.

Table G.3

Interrater agreement for muscle ratings for each level of FATM and SMM (i.e. each stimulus).

FATM level	SMM level	r_{wg} (n = 65)
1	1	0.29
1	2	0.41
1	3	0.40
1	4	0.34
1	5	0.26
2	1	0.57
2	2	0.65
2	3	0.53
2	4	0.45
2	5	0.55
3	1	0.69
3	2	0.61
3	3	0.58
3	4	0.54
3	5	0.60
4	1	0.74
4	2	0.64

4	3	0.68
4	4	0.68
4	5	0.66
5	1	0.68
5	2	0.70
5	3	0.73
5	4	0.74
5	5	0.74
6	1	0.58
6	2	0.65
6	3	0.76
6	4	0.74
6	5	0.66
7	1	0.62
7	2	0.67
7	3	0.68
7	4	0.63
7	5	0.66
8	1	0.62
8	2	0.59
8	3	0.61
8	4	0.64
8	5	0.63
9	1	0.60
9	2	0.63
9	3	0.58
9	4	0.63
9	5	0.66
10	1	0.52
10	2	0.54
10	3	0.58

10	4	0.54
10	5	0.56

Abbreviations. SMM, Skeletal Muscle Mass. FATM, Fat Mass.

Appendix H

Supplementary and exploratory analyses for Study 7 are presented here.

Psychometric Measures

Scores from psychometric measures were checked for multi-collinearity using Spearman's Rank correlations. There were significant positive correlations between scores on many of the psychometric measures (see Tables H.1 and H.2, for women and men, respectively). This demonstrates that the psychometrics are capturing a range of attitudinal and psychological concerns.

Table H.1

The relationship between psychometric measures for the female sample (n = 30).

Psychometrics	EDE-Q R	EDE-Q E	EDE-Q S	EDE-Q W	EDE-Q G	RSES	BDI	BSQ	Thin Ideal	Athletic Ideal
EDE-Q E	.72***									
EDE-Q S	.59***	.71***								
EDE-Q W	.57***	.67***	.91***							
EDE-Q G	.82***	.85***	.91***	.90***						
RSES	-.13	-.43*	-.64***	-.50**	-.49***					
BDI	.28	.34	.63***	.52**	.53***	-.80***				
BSQ	.73**	.78***	.93***	.90***	.95***	-.55**	.60***			
Thin Ideal	.74***	.59***	.57***	.52**	.68***	-.29	.35	.63***		
Athletic Ideal	.41*	.28	.19	.16	.29**	.28	-.02	.27	.40**	
DMS	.08	.12	.26	.33	.24	.08	.15	.29	.08	.53**

Abbreviations. EDE-Q R = EDE-Q Dietary Restraint. EDE-Q E = EDE-Q Eating Concerns, EDE-Q S = EDE-Q Shape Concerns, EDE-Q W = Weight Concerns, EDE-Q G = EDE-Q Global, Thin Ideal = SATAQ-4 Thin Ideal Internalisation subscale, Athletic Ideal = SATAQ-4 Athletic Ideal Internalisation subscale.

Table H.2

The relationship between psychometric measures for the male sample (n = 21).

Psychometrics	EDE-Q R	EDE-Q E	EDE-Q S	EDE-Q W	EDE-Q G	RSES	BDI	BSQ	Thin Ideal	Athletic Ideal
EDE-Q E	.37									
EDE-Q S	.22	.32								
EDE-Q W	.20	.25	.87***							
EDE-Q G	.57*	.58*	.85***	.80***						
RSES	-.09	-.24	-.81***	-.74***	-.65**					
BDI	.12	.13	.55**	.48*	.43	-.66**				
BSQ	.16	.19	.70***	.80***	.65**	-.65**	.64**			
Thin Ideal	.52*	.19	.65**	.62**	.67***	-.57*	.40	.56*		
Athletic Ideal	.45*	.30	.51*	.46*	.58**	-.25	.01	.34	.56*	
DMS	.48*	.28	.62**	.49*	.64**	-.42	.22	.28	.54*	.86***

Abbreviations. EDE-Q R = EDE-Q Dietary Restraint. EDE-Q E = EDE-Q Eating Concerns, EDE-Q S = EDE-Q Shape Concerns, EDE-Q W = Weight Concerns, EDE-Q G = EDE-Q Global, Thin Ideal = SATAQ-4 Thin Ideal Internalisation subscale, Athletic Ideal = SATAQ-4 Athletic Ideal Internalisation subscale.

For the female sample, SMM was significantly positively correlated with BSQ (r = .52, p = .004), SATAQ Thin Ideal Internalisation (r = .37, p = .045), and Athletic Ideal Internalisation (r = .43, p = .017). This indicates that increased actual muscle mass was related to increased body/shape/weight concerns and internalisation of both thin and muscular body ideals. Their BMI was significantly positively correlated with EDE-Q Restraint subscale (r_s = .45, p = .013), indicating that having a higher BMI was associated with increased dietary restraint. There were no significant correlations between the psychometric scores and actual fat mass, determined using Spearman Rank correlations (all *p*s > .05). For the male sample, SMM was significantly positively correlated with EDE-Q Global (r = .49, p = .024) and EDE-Q Restraint subscale (r_s = .58, p = .006). Their BMI was significantly correlated with EDE-Q Restraint subscale (r_s = .46, p = .034). This indicates that having a higher BMI and SMM was associated with increased dietary restraint. There were no other significant correlations between body size/composition and psychometric measures (all *p*s > .05).